OHG

SYSTEM BUILDING

THE ROLE OF THE ONTARIO HOUSING CORPORATION IN SYSTEM BUILDING

A REPORT PREPARED BY
PETER BARNARD ASSOCIATES

TORONTO AUGUST 1970

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August 18, 1970.

Board of Directors,
Ontario Housing Corporation,
188 University Avenue,
TORONTO 1, Ontario.

Attention: Mr. Paul R. Goyette,
Managing Director

Dear Sirs:

We are pleased to submit our final report following completion of our examination of the role the Ontario Housing Corporation should play in system building.

You will recall that this study was initiated in late 1969 amid considerable public and professional interest in system building and at a time when two multi-storey system builders had started construction of plants in the Toronto area and others had announced intentions of entering the Ontario market. Interest focused on OHC as the largest housing client in the Province.

Our objective in this study was "to evaluate all aspects of system building and to recommend how OHC might best use, or encourage the use of, system building in meeting its future housing requirements". Therefore, this report is the result of a policy development study and is not intended to be a treatise on system building.

The study focuses on four broad questions:

1. What is system building and how does it differ from Ontario's conventional housing industry? To answer this, we studied the characteristics of system building as well as Ontario's present housing industry.

2. What has been the experience with system building in other countries? We examined the reasons for the extensive development of system building in Europe and the present status of the industry there. We also studied U.S. government efforts to establish a system building industry.

3. Will system building be of sufficient benefit in Ontario to warrant strong government backing? We studied the nature of present housing problems and weighed the benefits system building has to offer, together with the likelihood of these benefits being realized in the light of its performance in other countries.

4. What programs are within OHC's powers and capability to implement? In formulating our recommendations we took into account OHC's powers and limitations, organization and personnel to ensure that the recommendations are capable of implementation and that the effort and expense involved in implementation is commensurate with the importance of this subject to OHC.

In arriving at answers to these questions, we have involved as many OHC personnel as possible, particularly in discussing our recommendations and how they should be implemented. Your interest and cooperation in this regard have been most helpful.

Finally, we would like to emphasize that this is not an academic research project. As a firm, we are committed to implementation and would not consider the project a success unless we have convinced you to implement our recommendations.

We have enjoyed working with you on this study, the findings of which have important implications, not only for OHC but also for the Ontario housing industry.

Yours sincerely,

Peter Barnard Associates

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CONCLUSIONS AND RECOMMENDATIONS

PART 1. SYSTEM BUILDING IN PERSPECTIVE

- The "systems approach" from which system building gets its name is an approach to problem solving that involves systematic analysis of the inter-relationships between all aspects of a process to ensure the best overall problem solution.

- The popular notion of system building has centered around technology, but applying the "systems approach" involves much more than this, and in fact system building is primarily an attempt to improve the organization and management of the total building process to achieve the full benefits of industrialization.

- There is no clear dividing line between system building and conventional building but there is a wide spectrum of technological, organizational and management forms between the traditional "one-off" building and the more advanced forms of system building. Ontario's housing industry, which is probably as advanced as any in the world, already has acquired many of the characteristics of system building.

PART 2. SYSTEM BUILDING IN OTHER COUNTRIES

- System building was developed in Europe following World War II to deal with two specific problems - huge backlogs of demand and shortages of skilled labour. It has generally proved successful in overcoming these problems.

- Governments provided the driving force behind system building by sponsoring its development and more importantly, by assigning large segments of their housing programs to it. This commitment provided the continuity of demand that is so critical to the success of system building.

- Cost reduction was not a primary motive in the development of system building, and despite the fact that it was competing against an inefficient traditional industry, it has achieved only modest savings with high rise buildings.

- Of the major types of systems developed in Europe, the large panel system has been by far the most successful and has been used primarily for multi-storey buildings.

PART 3. SYSTEM BUILDING IN ONTARIO

- While demand for housing in Ontario has outpaced supply since the mid 1960's, the cause of the accumulating shortage is not an inability on the part of the building industry to produce. On the contrary, when economic conditions have been "normal", the industry has demonstrated its ability to produce in sufficient volume to meet demand.

- The underlying cause of Ontario's housing problem is rising costs - cost of land, money and construction (labour and materials). As a result of these spiralling costs housing is beyond the means of a large and growing proportion of the population.

- Ontario's problems are clearly quite different from those of other countries where the motivation to develop system building was the large backlog of housing demand following World War II, in combination with a severe shortage of skilled labour.

- Because of the nature of Ontario's housing problems, system building cannot be viewed as a broad solution. Nevertheless, it could contribute to the solution if system builders can demonstrate their ability to control rising construction costs.

- A number of constraints will have to be overcome if system building is to be given the opportunity to compete effectively, but within the context of controlling construction costs there is a potential for it in Ontario.

PART 4. OHC'S ROLE IN SYSTEM BUILDING

- As one of North America's largest housing developers, OHC could provide the environment needed for system building to prove its cost-saving capabilities. Specifically, OHC could assist system builders to achieve continuity of demand and provide leadership in creating greater standardization throughout the building industry.

- OHC has certain relationships with the Federal and Provincial governments and with municipal and other authorities. It has responsibilities towards various groups and organizations including the conventional building industry. An examination of these relationships and responsibilities provides criteria which have been used in selecting the role that OHC should play - which is as follows:

  OHC SHOULD CONDITION THE ENVIRONMENT FOR THE DEVELOPMENT OF SYSTEM BUILDING SO THAT SYSTEM BUILDERS CAN EFFECTIVELY COMPETE. TO DO THIS, OHC SHOULD PROVIDE THE ARENA FOR FAIR COMPETITION BETWEEN SYSTEM AND CONVENTIONAL BUILDING.

SUMMARY OF RECOMMENDATIONS

1. Modify contract procedures to ensure continuity of demand.

OHC should modify its current contract procedures to permit the larger and longer-term contracts needed by system builders to achieve the full benefits of industrialization.

In addition to helping the system builder maintain economic levels of production and thus compete more effectively with the conventional builder, this program also offers the conventional builder the opportunity to make bulk purchases and achieve some economies of scale.

OHC should initiate two programs in this regard:

Multi-Site Contracts

To aggregate demand and allow larger and longer term contracts, OHC should group requirements for several projects within a given geographic area into a single proposal call.

Serial Contracts

OHC should initiate a new type of proposal call whereby the successful proponent would be given the opportunity to obtain contracts for buildings of equivalent size and design characteristics in each of two succeeding years, based on the initial price.

2. Initiate a program of dimensional standardization of OHC dwellings.

OHC should undertake a major program of dimensional standardization to foster greater industrialization of the building process by system, conventional and component builders.

OHC, by virtue of the size and characteristics of its programs is uniquely positioned to lead the way to the standardization of dimensions, plans and sub-systems that is so badly needed to achieve higher levels of industrialization.

Standardization, as we shall show throughout this report, is the basis of industrialized building. Achieving greater standardization will be of great benefit to system and conventional building, although the greatest benefit may accrue to component manufacturing, an evolutionary trend that we have noted in Ontario and a development that, if encouraged, may in the long run provide the best solution to the problem of holding down construction costs.

In order to achieve maximum benefits of this program, OHC should strongly support current efforts to achieve uniform building standards for the entire province.

3. <u>Develop and encourage long range planning</u>.

OHC should assume a leadership role in developing forecasts of housing need, in formulating long-range housing plans for the province and in encouraging municipalities to develop projections of their own housing requirements.

The existence of long-range housing forecasts and plans would assist the housing industry in adopting a much more planned approach to the building process. As we shall show, system builders in particular must be able to plan for future production. Furthermore, these forecasts and plans will assist OHC's land purchasing activities upon which the multi-site and serial contracting procedures would depend.

4. <u>Sponsor an annual competition for innovative housing.</u>

OHC should initiate an annual competition to stimulate the development of new and creative solutions to housing problems.

One of the major obstacles to the implementation of new ideas in the housing industry is lack of opportunity to test them in use. The private housing industry, with its limited resources, is unwilling either to pay the premium typically involved or to accept the risks. Thus, OHC can perform a valuable service to both system builders and conventional builders by providing the opportunity to test new ideas in use.

5. Undertake a program of applied research and development

OHC should undertake a sustained program of research and development to provide much needed support for the application of new methods, improved designs and innovative products in the Ontario housing industry.

There are limited facilities in Ontario for accumulating and disseminating research findings and developments in building technology or for sponsoring investigations that would specifically benefit the Ontario industry. OHC's position as a government agency and largest builder and manager of housing in the province makes it the logical candidate for performing this important function.

1

SYSTEM BUILDING IN PERSPECTIVE

System building is one of the most discussed and analyzed subjects in the building industry today and, as with most over-exposed topics, has developed a range of interpretations and misunderstandings. The popular notion of system building centres around technology but in fact system building involves much more than this. Our purpose in this first part is to put system building into its correct perspective by comparing it to conventional building in terms of technology, organization and management.

For purposes of comparison and illustration we have taken conventional building in its most simple and traditional form and system building in its more advanced form. In fact, there is a spectrum of forms ranging between the two and the conventional industry in Ontario is actually well along the continuum.

First we shall review the so-called 'systems approach' to problem solving which is now being used throughout industry and from which system building derived its name. Then we shall describe system building in some detail by comparing its technology, organization and management to traditional building. In the last chapter, we shall review Ontario's building industry in relation to system building. Finally, since our investigations have gone considerably beyond what is included in this part of the report, we include more technical analyses of the implications of system building in Appendix A.

THE SYSTEMS APPROACH TO THE BUILDING PROCESS 1·1

We should first like to clarify some terms to provide a basis for discussing what system building is and how it fits into the total perspective of the Ontario housing industry.

THE SYSTEMS APPROACH ENCOMPASSES THE TOTAL PROCESS

The traditional approach to planning and problem solving tends to consider the various functions and activities that are involved in the process in isolation from one another. The 'systems approach' encompasses the whole. It involves a systematic analysis of the interrelationships between all aspects of a process to determine the impact that actions with respect to one point of the process will have on others. This often produces better and more innovative solutions to problems, since the best solution to a problem may involve changes to an apparently unrelated part of the process.

The systems approach is particularly valuable for processes involving the coordination of different skills and functions where decisions taken by one group can have an effect on others. It has been successfully applied in the aerospace and electronics industries where projects involve not only different skills and functions but also different manufacturers of sub-systems, all of which have to function together for a successful project.

SYSTEM BUILDING IS AN APPLICATION OF THE SYSTEMS APPROACH

From initiation to completion of a project the building process involves a variety of skills provided by owners, architects, builders, engineers, manufacturers. Traditionally these functions have been specialized and to a great degree isolated from each other. This traditional approach works well for unique, one-off buildings. It has not proved effective for large-volume, repetitive work such as housing.

Production can be speeded up by applying high-volume manufacturing techniques - that is by industrializing the building process. Industrialization requires the continued cooperation of everyone involved to achieve the full benefits, not only to develop the technological solutions required for the physical aspects of the building process, but also the means by which projects are completed - the management and organization.

Thus, system building, the main subject of our study, is an application of the systems approach whose purpose is to realize the benefits of industrialization of the building process. It is the application most frequently used to date, although it is not necessarily the only one, as we shall point out later in this report.

THE BUILDING PROCESS INVOLVES TECHNOLOGY, ORGANIZATION AND MANAGEMENT

To provide a basis for describing system building and how it differs from conventional building, we will consider that the building process involves three inter-related aspects - technology, organization and management.

Technology is the "nuts and bolts" of building - such physical aspects as the materials, products and components which make up a finished building, and the way they are put together. To borrow a phrase from the computer industry, the technology is the "hardware" of building.

There are various ways and means by which people and resources can be organized and managed in order to use this technology to produce a building. This could be called the "software" of building. And while organization and management are related, we see a distinction between the two terms:

Organization concerns the inter-relationships between the five main functions involved in the building process: use, ownership, design, build and manufacture. Each of these functions is normally the responsibility of one set of participants in the building process (Figure 1.1). In housing

ORGANIZATION CONCERNS THE RELATIONSHIP AMONG THE MAIN PARTICIPANTS IN THE BUILDING PROCESS

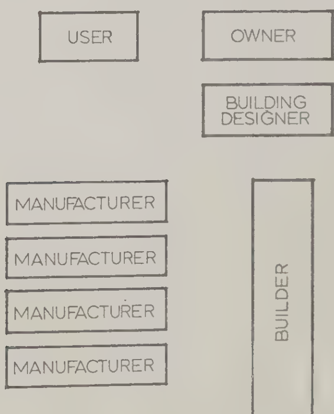


FIG. 1.1

Source: Refs.65, 69, Peter Barnard Assoc.

for example, the user is the occupant; the owner is typically a developer or government agency; the designers are architects and engineers; the manufacturers are the various building product and component suppliers; the builders are contractors and sub-contractors.

Management means the control which must be exercised over physical, financial and human resources in order to carry the building process to a successful conclusion.

New or misunderstood topics are best explained by reference to a common understanding. To contrast with the technology of system building we will first describe the essential features of building technology as we know it today. To heighten the contrast we will use the most "traditional" forms of conventional technology in our discussion such as might be used in a custom-designed house or office building.

TRADITIONAL BUILDING EMPHASIZES ONE-OFF DESIGN, ON-SITE CONSTRUCTION

The technology of traditional building has two important characteristics: the design for each project is unique and the construction methods involve on-site construction using materials and minor components delivered to the site.

Uniqueness of Design

A fundamental concept in traditional building is the attempt to tailor each building to the specific needs of its users and to the unique requirements of its site. Each building tends to be different from the next even when occupancy types and site characteristics are similar. This is particularly true of the major structural elements: structural layout, floor thicknesses and spans, column sizes and wall dimensions typically bear little or no relationship

from one building to the next. Other major components such as cladding, partitioning, plumbing and heating systems are also 'custom' designed specially for each project.

This is not to say there is no standardization. In housing, for example, simple components such as plumbing fixtures, appliances, tiles, bricks, bathroom and kitchen cabinets, doors and windows are mass-produced and supplied in a limited variety of forms by various manufacturers of building products. Although these components are standardized, jointing details vary and usually require either a considerable amount of detailing at the design stage and/or cutting and fixing on site.

Therefore in traditional buildings there is little or no standardization of structural components and only uncoordinated standardization of minor components.

On-Site Construction Activities

The fact that much of the actual building takes place on site requires a considerable amount of skilled and non-skilled labour. The major components - both structural and non-structural - are built from basic materials delivered to the site. Minor components manufactured in plants are also shipped to the building site and fitted into the site-constructed components. This process requires close coordination of a variety of skilled crafts working together on site. Their work is largely manual, involving much cutting and fitting.

On-site production involves some disadvantages, the major one being the production limitations of the process. Construction is largely sequential, with men and materials needed for one operation (say, placing floor concrete) having to await completion of other tasks (forming and placing reinforcement). Once the builder has developed an efficient

scheduling of these sequential operations, it is very difficult to speed up construction further.

Traditional building is also highly vulnerable to delays for a variety of reasons, such as late delivery of materials, weather conditions and disputes with the various craft unions involved. Quality of workmanship is also sensitive to things such as exposure to adverse weather conditions and the need to work in awkward, sometimes almost inaccessible spaces.

On the other hand, on-site production provides a great degree of flexibility. It requires very little capital investment, most of the equipment for construction being leased for the duration of a project. More important, it requires no permanent construction team. Skills are brought in and released as required, usually as sub-contractors. This is a very useful facility given the uncertainties of the industry.

STANDARDIZATION PROVIDES THE BASIS FOR SYSTEM BUILDING TECHNOLOGY

System building technology differs from both major characteristics of conventional building: it involves standardized rather than one-off design; it implies in-plant rather than on-site construction.

Limitation on Variety

The goals of industrialization of the building process are improvement in productivity and faster construction speed compared to the relatively non-industrialized, craft approach of traditional building. Improvements in efficiency and

productivity can be realized by replacing the on-site craft skill requirements with factory production techniques. However, these techniques require repetition, a characteristic not normally present in the one-off nature of conventional building except in its already industrialized basic materials and products.

The basic characteristic of system building technology is its standardization of major components, particularly those comprising the building structure. This standardization permits repetitive manufacture and justifies capital investment in plant and equipment for factory production. Component designs must be sufficiently varied to meet reasonable market requirements, yet be repetitive enough to permit economical manufacture.

The primary areas for standardization are in dimensions and materials - that is, components are produced in a limited range of sizes using a given material or combination of materials. A building system also limits the variety of finishes available for most components. Those most visible, such as cladding, normally have several standard finishes.

Standardization, because of the implied limitations on variety, tends to be regarded as implying uniformity, monotony and sterility. There have been applications of system building where this criticism would apply, but this need not be the case. Levels of standardization can be achieved which permit the benefits of industrialization while still allowing the design flexibility needed to produce non-uniform, attractive buildings that are indistinguishable from those built conventionally.

Three Forms of Structural Standardization

No building system could be developed which did not incorporate standardization of major structural components. The structure establishes the overall dimensional framework for a building without which standardization of other major components would not be possible. Many building systems involve industrialized manufacture of structural components only, leaving the rest of the building to be constructed by traditional means. There are three basic types of building systems: frame, panel and box.

- Frame systems. These involve the standardization of columns, beams and girders and their physical co-ordination (Figure 1.2). Such systems can be likened to an erector set and represent a fairly simple technological development from traditional building.

  Frame systems are often used in conjunction with panel systems for the infill walls, floors and roofs. Concepts have also been proposed in which box apartment modules are inserted into a multi-storey frame system.

FRAME

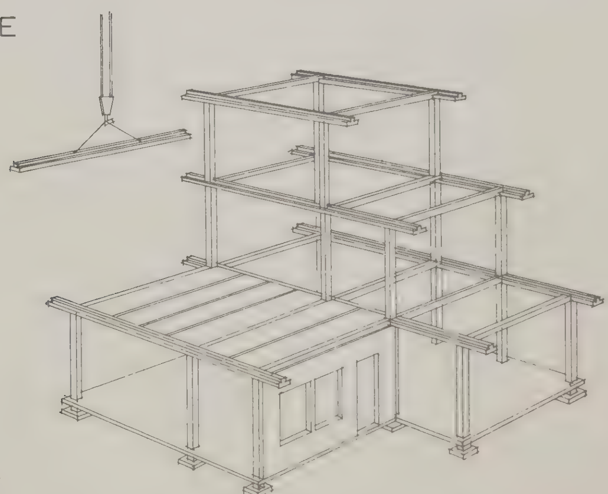


FIG.1.2

Frame systems employ steel as the primary material, although wood and concrete have also been used. While they have been used for low-rise housing, primary application has been where interior design flexibility is important, most notably, schools.

Most well-known frame systems have been intended for use in school construction including CLASP (U.K.), SCSD (California), SEF (Toronto) and RAS (Montreal). Examples of housing systems using frames are Berolano (Italy), Borini (Italy), Arcal (U.K.), Polyvilla (Belgium), Konstrictiva (Czechoslovakia) and Componoform (U.S.). However, frame systems for housing have not been particularly successful in that none has achieved a large share of its potential market.

- Panel Systems. This type of structural system uses large wall and floor components which are assembled on-site to form either crosswall or exterior bearing wall type structures (Figure 1.3). Concrete panel

PANEL

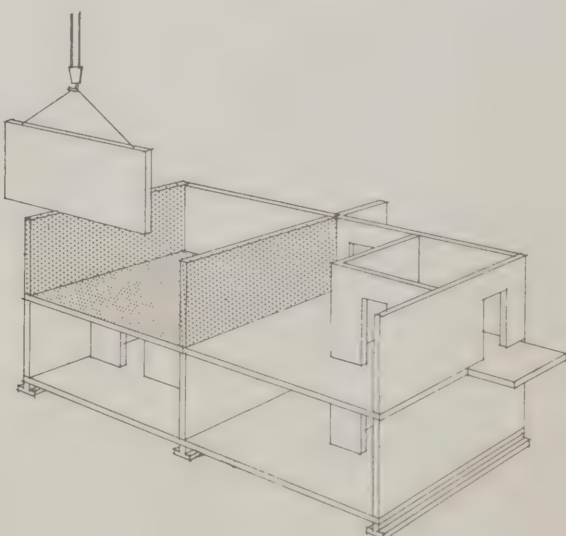


FIG.1.3

systems have been used extensively for high-rise, and to a limited extent, for low-rise housing. Wood panel systems have been more successful in low-rise applications.

There are too many (several hundred) panel systems available to detail them all. Dominant among these, however, have been such systems as Jespersen (Denmark), Wates (England), Larsen Nielsen (Denmark), Skarne (Sweden), Balency, Coignet, Tracoba and Camus (all France).

The first two of these systems were introduced during the past year to Canada and now have plants in operation in the Toronto area; others have been licensed for use in Canada but are not yet in production.

- Box Systems. This type uses three-dimensional components (sometimes called modules) (Figure 1.4).

BOX

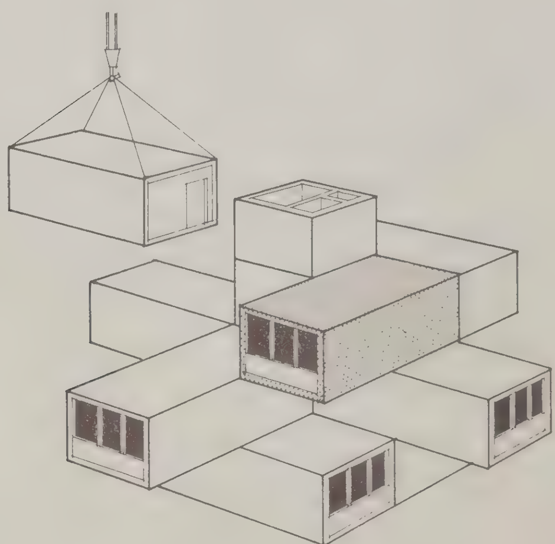


FIG.1.4

They represent the most advanced system building technology and permit the highest level of factory production. Some are completely finished in the factory down to furniture, paintings on the walls and dishes in the cupboards.

Concrete box systems were first used in Israel and Russia but have attracted increasing interest in North America for use in multi-storey buildings. The best-known is Expo '67's Habitat. Others are Uniment and Zachry, both U.S. developments currently licensed in Ontario, the latter already in production.

The application of wood or metal box systems to low-rise housing is a typically North American development. Mobile and sectional home manufacturers, such as Boise Cascade, Stirling Homex and Skyline Corporation in the U.S. and Alcan and Atco in Canada have large production capabilities mostly aimed at the single-family or row-house market. Concepts for steel box systems have been developed in the U.S. and by Stelco in Canada, while TRW is currently testing a matted glass-fibre-reinforced plastic box system.

Differences Between System Types

The three types of system represent progressive development from the frame system which is the simplest and most like conventional, through the panel, to the box system. Along the spectrum from frame to panel to box there is:

- Increased standardization of building forms and layout (and decreased flexibility of interior and exterior design);

- Fewer separate structural components;
- Greater weight and a need for increased capacity of handling equipment;
- Greater potential for factory production;
- Greater potential for standardization of components other than the structure.

Standardized Sub-Systems

The more advanced building systems carry standardization beyond the structure to allow industrialized manufacture and assembly of other components and sub-systems, such as cladding, partitions, plumbing and electrical systems, built-in furniture, etc., which account for a substantial proportion of the total building cost - much more than the structure alone.

This prefabrication of sub-systems saves on-site exertion time and reduces the amount of skilled labour required. (Sub-systems, such as kitchen-bathroom cores, interior and exterior walls, heating and plumbing systems and furnishings when assembled on-site account for most of the skilled labour content.) Manufacturing sub-systems off-site allows some work to be completed coincidentally that under conventional construction would have to be done in sequence, thereby reducing construction time.

Moreover, such sub-systems typically involve fairly intricate assembly which can be more easily and cheaply completed in a factory than on-site. Since the completed assemblies are light and relatively small, they can be easily transported from the factory to the job site.

In moving towards the goal of greater industrialization of the building process, sub-system production is extremely important, not only because a large proportion of total building cost is tied up in sub-systems, but also because many of them are well suited to industrialized production.

Jointing Decisions

The more complete the building system, the more important overall dimensional coordination and jointing become. In a building system which concentrates on production of major structural components, the only jointing decisions that need be made concern the structural connections. The remainder of the building could be completed using conventional site-fitted construction. The addition of other standard components to the system package makes overall coordination vital and requires the designer to make many more decisions on joint conditions. The complete building system must have all jointing conditions fully rationalized, with provision made for design and size variations of all available components.

Less Site Activity

Except for foundation work, which normally must be carried out by conventional means, site activity in system building becomes more and more an assembly rather than a construction process. Emphasis switches to the use of sophisticated erection techniques and closely controlled erection schedules in order to achieve the greatest possible construction speed. Site labour is reduced, particularly that of the skilled finishing trades.

As a result, system building tends to be faster than conventional construction. In addition, the component assembly operations of system building are not as sensitive to weather interruptions as conventional on-site methods.

ORGANIZATION IN SYSTEM BUILDING 1·3

In this Chapter we will again contrast the organization of system building with that of traditional building.

TRADITIONAL BUILDING ORGANIZATION IS SEPARATED

In traditional building, the various functions are usually the responsibility of wholly independent individuals, groups or organizations. Users form a distinct group and while other participants such as owners or designers may study their needs, the users themselves are seldom involved directly in the design or building process. The owner also is usually a separate individual or organization, who typically concentrates on planning, financing and marketing. He also exercises control over the other participants. Design is carried out by independent firms or staff designers, usually architects, who in turn rely on independent firms of consulting engineers for specific structural, mechanical or electrical design requirements. Similarly, the manufacturers and builders are separate organizations, the latter normally engaging independent sub-contractors for major portions of the construction work.

This dispersion or separation of functional responsibilities is one of the major characteristics of traditional building. In bringing them together to carry out a project, several organizational forms have evolved. The direct tender approach is the best known.

Direct Tender Organization

In the direct tender organization, each function is completely separated from the others. The owner normally determines the general nature of the users' needs. He commissions a designer and sets the process in motion. Design drawings and specifications are produced, from which a contractor is chosen by competitive tendering. Manufacturers are coordinated to supply materials and components to the contractor. The direct tender approach is illustrated in Figure 1.5.

Separation of functions is a major weakness of the direct tender method because most functions are naturally inter-related. Ideally, design should be carried out with full knowledge of the construction organization which will carry out the work, of the manufacturing facilities to be employed, and of the owners' financial and marketing plans. Although some of this information can be transferred from one organization to the next, the separation of the various functions makes control extremely difficult.

DIRECT TENDER ORGANIZATION SEPARATES PARTIES AND THEIR FUNCTIONS

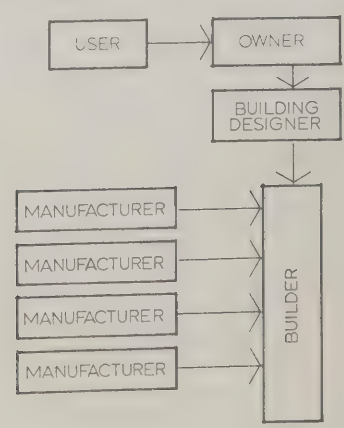


FIG.1.5

The direct tender approach has some other significant organizational characteristics:

- Limited interaction amongst participants: Organization is at "arms length" rather than integrated, with each participant concentrating on his own functional responsibilities. For example, the building designer's primary concern is with design and while he may attempt cost control and project scheduling in his client's interests, in the final analysis it is the builder who controls this. There is little other interaction. The owner normally relies on the designer to act on his behalf and has little contact with, say, the manufacturer or the builder except for his contractual arrangements with the latter. Similarly, the builder or manufacturer have little or no relationship with the user, and so on.
- Difficult Project Control: The fact that the various functions are carried out by independent firms makes overall coordination of the project difficult. This is a major weakness. The designer can exert only limited control over the project because he bears no direct responsibility for major portions of the work (particularly building and manufacturing).
- No Continuity: There is a lack of continuity amongst participants from one project to the next. The owner may not choose the same designer and even if he does, the tender process may result in different manufacturers and builders becoming involved. As a result, important working relationships must be re-established with each new project.

SYSTEM BUILDING INTEGRATES FUNCTIONS AND PARTICIPANTS

One of the most significant characteristics of system building is the concentration of conventionally separate functions into a single organization. As a result, there is greater integration of the various participants than with traditional building. In addition, system building involves new functions (hence new types of participants), changed roles for other participants, and new organizational forms.

New Functions and Participants

With system building two new functions are added to the building process.

- System Design: The design of a building system involves a complex process of studying the needs of the user and market to be served, and the development of a form of standardization of components which will meet these needs satisfactorily yet be capable of efficient manufacture. This is a function quite different from building design, and it requires combinations of skills not normally present in a designer of conventional buildings. The system designer becomes an important new participant and his analysis of user needs and his development of the system concept are critically important to the overall success of the building system (Figure 1.6). The system designer does not replace the building designer, although the latter's role is, of course, altered.

THE SYSTEM DESIGNER IS AN IMPORTANT NEW PARTICIPANT IN SYSTEM BUILDING

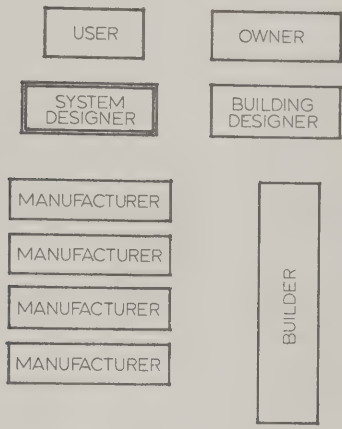


FIG. 1.6

- Sponsorship: A second new function in system building is that of initiating and guiding the development of the system. The so-called "sponsor" of a building system is the person or organization taking the initiative in developing the system. Once the system has been developed and is in production, then the sponsor controls its further development, modification and marketing. Sponsorship is usually exercised in combination with one of the other functional responsibilities. That is, the sponsor of a building system can be the owner, user, system designer, building designer, manufacturer or builder.

He may also be an "outside" party not normally associated with the building process, who sees the system as an investment opportunity.

New Organizational Forms

New organizational forms emerge under the sponsor's leadership, involving greater functional integration and close coordination amongst participants. These organizations are normally associated with the sponsorship type and their nature is strongly influenced by the sponsor.

- Owner-sponsored System: The owner-sponsored system has been used most frequently when the owner is a school board or housing authority with a continuing building requirement. The objective for initiating the system is usually concerned with achieving cost savings, improving performance or both. While the forms of organization can vary, the two most common are illustrated in Figure 1.7.

OWNER SPONSOR

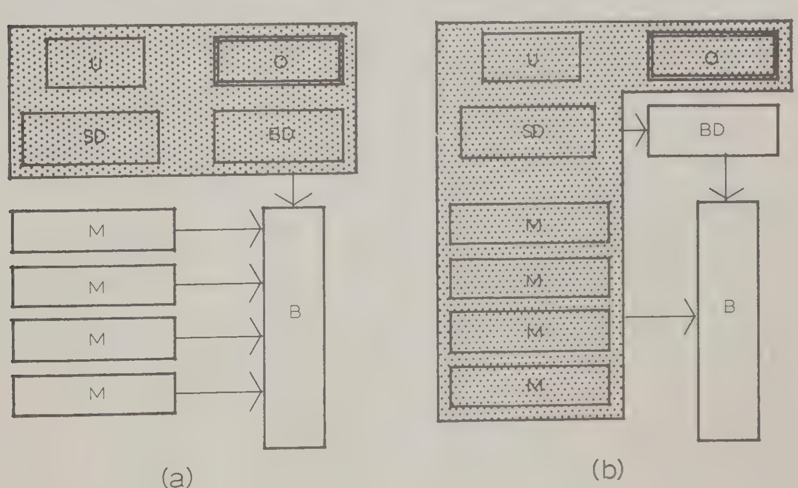


FIG.1.7

The form shown in (a) has often been used by a housing authority with in-house design capability. The design staff makes some assessment of the needs of the users and then develops a system for use in its own projects. Building design is also handled by in-house designers. This method has been used in England where the SF1 system developed by the Greater London Council is perhaps the best known. In this case, a manufacturer of cladding panels was brought into the system but other components were tendered in the usual way.

The form shown in (b) has been employed in several school systems, notably SCSD in California, SEF in Toronto and RAS in Montreal. In these instances, the owners conduct an intensive user study on which to base decisions on dimensional standardization and performance specifications for building components. In designing their systems the owner-sponsors stop short of designing individual components and instead receive bids from component manufacturers on a design and install basis. Compatability of components is ensured either through the specifications or by requiring the manufacturers themselves to perform the necessary coordination function. Information about dimensional standardization and components are supplied to building designers who prepare drawings and specifications for the builder.

A third form of owner-sponsorship may be particularly important for North American housing. This occurs when an owner or builder, who already has land holdings and a building program of his own, decides

to develop or acquire his own system. No doubt he will also attempt to sell his system outside of his own building program, but he will be able to count on his own building program as a base load for his manufacturing facility. Owner-sponsors in this category include Modular Precast Concrete Ltd. and Bramalea Development Corp. in Toronto (with Wates and Skarne systems respectively) or Levitt and Sons in the U.S.

- Builder-sponsored Systems: A builder will decide to develop a system if he feels that it will increase his markets, eliminate some of the large fluctuations in his activity imposed by the conventional tender approach, and cut his construction costs. For a housing system, he will make decisions, along with the system designer, on the nature of the system in order to satisfy basic user requirements. Normally, he will not undertake extensive studies in this regard but must make sure that the design of buildings constructed using his system will be acceptable to users, owners and government authorities. The builder will then establish manufacturing facilities to produce the system and bring manufacturers of other products into the system to the degree which he feels their products will provide a more marketable total package. He may also decide to bring building designers into the team in order to offer an even greater service and to ensure that buildings are designed as efficiently as possible using the system. This organizational form is shown in Figure 1.8.

BUILDER SPONSOR

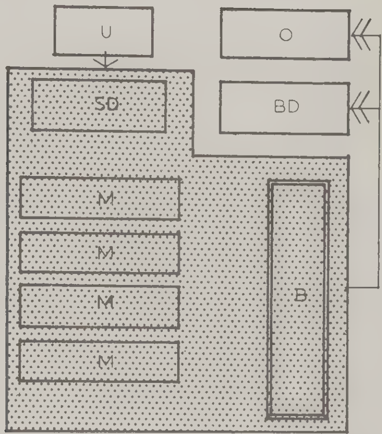


FIG.1.8

The builder-sponsored system has an important requirement, hardly present in owner-sponsored systems: the need to market the system (shown by double arrows in Figure 1.8). Owners must be convinced of the advantages of using the system, both from functional and cost points of view. If the system sponsor feels that the opinions of the clients are such that staff building designers cannot be used, then the system must also be marketed to outside building designers. This has been the experience of some British systems which have concentrated their marketing on the architect.

As we said earlier, the system usually emphasizes the skills and interests of the sponsor. Consequently, builder-sponsored systems are characterized by efficient on-site construction techniques, reflecting the builder's major area of expertise in the conventional industry. Perhaps because of his experience with conventional building, the builder has been by far the most successful of all system sponsors. Well-known names such as Jespersen, Wates, Camus, Larsen and Nielsen, Skarne and Balency were all originally builder-sponsored. Some have since been franchised to others.

- Manufacturer-sponsored Systems: Motivation for a manufacturer to sponsor a system is similar to that of a builder: he wishes to expand the markets open to him. In this case, he may also want to increase the markets for products or materials he already produces for the conventional industry. Typical organizational forms are similar to those of builder-sponsored systems. The manufacturer-sponsor coordinates other manufacturers supplying products (they may even hold shares in the system company) and design is carried out by a system designer. In this case the marketing effort must be directed towards building designers and owners, while builders must be acquainted with appropriate construction techniques and scheduling procedures in order to make the most efficient use of the system. The sponsor may also decide to bring a building designer and/or a builder into the group. This may improve efficiency but the sponsor must justify in his own mind that he would not be eliminating possible markets by doing so.

Manufacturer-sponsored systems tend to emphasize the production skills of the sponsor. Suppliers of precast concrete, wood and steel products to conventional building have been the most common types of manufacturer-sponsor who can bring some marketing skills into the system. Though generally not as numerous or well-known as builder-sponsored systems, some manufacturer-sponsored systems exist, such as Bison (Concrete Limited) in the U.K., Alcan Universal Homes in Ontario and National Homes and Boise Cascade in the U.S.

- Designer-sponsored Systems: Systems have also been initiated by designers whose interests and skills are primarily technical but who are usually motivated by a desire to improve the quality of the environment by eliminating some of the overly-standardized aspects of other system types. The concepts of the system are usually well thought out and frequently the technical features revolve around some novel component or detail. As a rule, designer-sponsored systems have not been very successful, although names like Techcrete (U.S.) and Arcal (U.K.) have enjoyed some success. The reason for the general lack of success of this sponsorship form stems primarily from the fact that the designer lacks the detailed production, construction and marketing skills necessary for a successful system, as well as the financial backing needed to acquire these skills. In certain respects this is unfortunate because many worthwhile system concepts do not reach the production stage.

- User-sponsored Systems: This sponsorship form has not been used with any success because the user lacks virtually all the skills required and may even not have the capability of enumerating his own needs. However, movements for greater user participation in urban development will undoubtedly lead to attempts at user-sponsorship. A concept of joint sponsorship with another important participant such as a builder or owner would probably be the best answer for user participation. This approach has been tried by some Swedish cooperatives.
- Outside-party Sponsored Systems: A particularly important development in North America is sponsorship of building systems by an organization outside the conventional building industry who sees system building as an investment opportunity. Normally, an outside sponsor is a large corporation with many of the necessary skills and resources such as financial, manufacturing, management and marketing needed for the successful development of the system. This type of sponsorship is characterized by a very calculated management approach to the venture and the application of large amounts of capital. The outside sponsor's main weakness tends to be his lack of knowledge of the building industry. He must, therefore, rely on the ability of his system designer and other consultants to advise him and their advice could well determine the success or failure of the venture. One organizational form for outside party sponsored systems is shown in Figure 1.9.

OUTSIDE PARTY SPONSOR

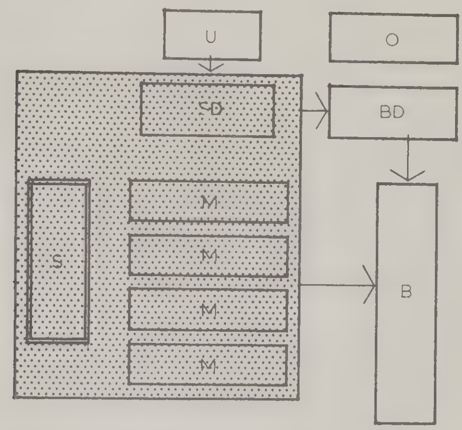


FIG.1.9

Decisions regarding whether or not to include a builder or building designer on the team relate to the sponsor's approach to marketing the system. If he feels that owners are receptive to package deals, he may decide to bring in both a builder and building designer. Alternatively, if the market is such that building designers make the key decisions and a conventional tendering approach is still favoured, then he will leave both builder and designer off the team, concentrate marketing activities on building designers and then make sure that the chosen builder is instructed in the proper use of the system.

Most examples of North American outside-party sponsored systems are well-known but, as yet, relatively unproven. They include Jespersen-Kay and Polymer Corporation in Canada, and TRW Systems Group, General Electric, Lockheed Aircraft and Westinghouse in the U.S.

- Joint-sponsorship: Sponsorship need not be restricted to a single participant. In fact, combined sponsorship such as owner/builder, builder/manufacturer or designer/builder may overcome some of the shortcomings of the individual sponsorship forms. In these cases, the joint sponsors would band together initially to develop the system concept and would probably have joint ownership of the company.

Different Functional Responsibilities

The organizational forms of system building described above involve some major shifts in importance and responsibilities for the participants from those in the traditional building industry.

- User: The correct identification of the needs and preferences of the user is particularly critical in the development of a building system intended for the private market. The interpretation of these needs and their translation into building component designs by the system designer provides the basis for establishing production facilities which require large capital outlays. Mistakes in assessing user needs will be reproduced many times over or else the production facilities will have to be modified to correct matters.
- Owner: Unlike traditional construction, the owner

cannot commission an uniquely designed building. He must choose between available systems each giving a range of available solutions or pay a premium to have a system modified to suit his particular requirements.

- Building designer: Clearly the building designer becomes considerably less influential in system building. He yields much responsibility to the system designer and must conform to the rules for standardized products which the system designer establishes. However, the quality and economy of the final product is still very much dependent on his skills.
- Builder: The builder becomes more an assembler and coordinator of components and is involved in less on-site activity. His skilled labour requirements will drop but his scheduling practices will have to be improved to meet the demands of factory production lines.
- Manufacturer: Particularly if he is concerned with major components, the manufacturer assumes a more important role in system than in conventional building. He may take on a greater range of activities, be more concerned with site operations, become closely associated with building design and specialized sub-systems.

Again a comparison of traditional and system building can help illuminate some marked differences:

TRADITIONAL BUILDING REQUIRES LIMITED MANAGEMENT SKILLS

Because of its informal organizational structure, traditional building requires a rather low level of management skills.

On-Site Management

The major management requirement is concentrated at the construction site (Figure 1.10). Men, materials, equipment and small components must be coordinated on-site, putting great emphasis on cost control and scheduling. Since the amount of interaction amongst the various companies associated with a project is limited, the problem of managing the process is not a major one - so long as each organization functions properly and on schedule.

Other Management Skills

Apart from project control, management requirements typical of most industries are largely absent from the traditional building industry.

THE ON SITE CHARACTER OF TRADITIONAL CONSTRUCTION
REQUIRES LOW LEVEL OF MANAGEMENT SKILLS

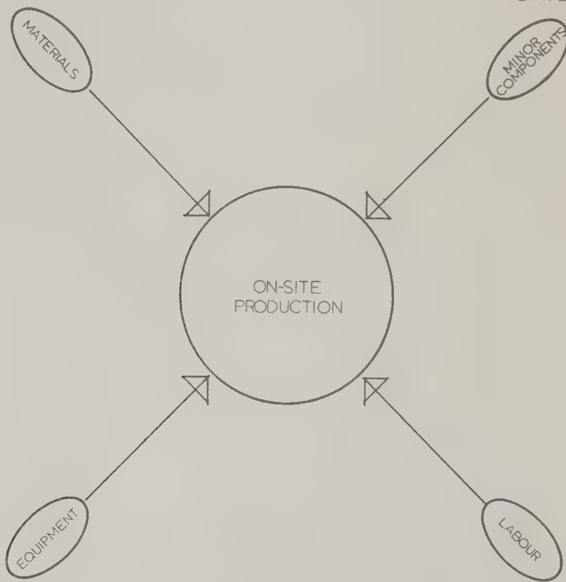


FIG.1.10

- Marketing: Outside of the manufacturer, marketing and promotion efforts by other participants are limited. Designers and contractors do not require marketing skills since they receive commissions largely on the basis of merit and low price tendering respectively. The marketing effort of manufacturers is directed at designers (to get products specified) and contractors (to avoid substitutions).
- Finance: A builder's capital investment is usually very low. He normally prefers to rent expensive equipment on a project-by-project basis in order to avoid having to carry equipment costs when not

essential in tender competition. Sub-contractors and designers also have little capital investment.

- Planning: The on-off nature of traditional building makes planning very difficult. Builders and designers, because they have little control over when they will be busy and when they will not, can only undertake general operational planning. Employment in both types of business is elastic, swelling during peak periods and shrinking during downturns and with virtually no market control both short and long term planning is almost impossible.

SYSTEM BUILDING REQUIRES ADVANCED MANAGEMENT

System building requires more comprehensive management skills than those used in traditional building. The more complex the system in terms of production facilities, sub-system integration and organizational structure, the greater the management task becomes. The major areas of increased management responsibility are in marketing, co-ordination and control of operations, finance and planning.

Marketing

For many possible sponsors of a building system one of the most important new management requirements is the need to promote and sell the use of the system. In the traditional industry, builders, designers, some owners and even some types of manufacturers have had little marketing experience because the nature of the industry does not require much marketing expertise.

With a building system, the sponsoring organization must now undertake a considerable marketing effort to convince key decision makers of the merit of the product and thereby ensure that the costly manufacturing facility is producing at an economical rate. The complexity of the marketing problem is somewhat dependent on who these decision makers are. In a country where government controls a large proportion of housing production, then marketing is directed at government and can have political overtones. In a more free-enterprise economy, the system may have to be promoted to many decision makers such as owners, designers, and builder/developers.

Research becomes an important new tool of the marketing-oriented system builder. He uses it to develop system refinements, new products and sub-systems and to ensure continued user satisfaction with his product.

Coordination and Control of Production

The entire production process takes on a new degree of complexity in system building. Marketing must provide orders for the system, but from that stage coordination of a broad range of activities becomes very important. We have illustrated some of these activities in Figure 1.11. The industrialized production process - usually a single factory, but sometimes an aggregate of several factories as in an owner-sponsored system - must coordinate men, materials, equipment and minor components into a smooth production cycle, which must in turn be coordinated with a number of sites. Clearly, this is a system in itself with much inter-dependency. Delays on site create inventory problems at the factory. Delays in the supply of

COORDINATION AND CONTROL BECOMES A MAJOR MANAGEMENT TASK IN SYSTEM BUILDING

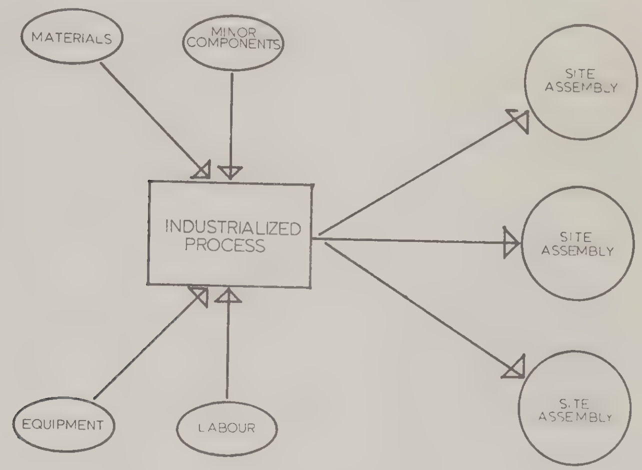


FIG.1.11

even minor components to the factory could create site delays.

The interaction between the marketing and production functions creates what is probably the system builder's most important problem - scheduling. To obtain maximum return on investment, the production facilities must be kept busy. However, consider the situation of a system builder with a multi-storey system for which orders might be in 300 unit lots (an average building). Each order could amount to 1/3 of his year's production. If, in a year, 3 orders occupy his entire production, the timing of these orders becomes critical. Owners can seldom be convinced of the

need to wait for another person's order to be shipped before his. Two orders received simultaneously create problems... no orders cause problems.

Financial Control and Planning

The large capital cost of plant and transportation and erection equipment requires considerably more financial control than most participants in the traditional industry are familiar with, since the total capital investment is considerably more.

The system builder must also absorb large expenditures in development and testing of the system and in the continual modifications necessary. Furthermore, marketing, promotion and start-up expenses are high.

Along with all of the other management requirements discussed above, the system builder is under more pressure to plan the future development of his company. This will require financial forecasts based on accurate assessment of the market, the performance of competitors and demand for his own product.

In short, the system builder requires management skills similar to those of any industrialized product manufacturer and faces particular problems connected with the probable on/off nature of production scheduling and the complex, fragmented nature of the industry he serves.

Like any other industry, building is undergoing continual evolution in its technology, organization and management. In previous Chapters, we have compared system building with the most traditional or craft-based form of building as a means of emphasizing the fundamental differences between the two. The status of the building industry in Ontario today is in fact considerably more advanced in all respects than the traditional form. In this Chapter, we will show that there is no clear cut dividing line between system and conventional building and that Ontario's housing industry already has many of the characteristics of system building.

TRADITIONAL VS SYSTEMS - THE MAIN DIFFERENCES

It will be helpful to summarize the main differences between traditional and system building.

Technology

As we described earlier, the major building components in traditional building are different from one building to the next. This requires considerable on-site skilled labour to convert basic materials and minor components on-site. To reduce skilled labour content and to make the overall process more efficient, system building attempts to remove

the construction of at least the major structural components into a factory where a more industrialized form of production can be used. This type of production process requires repetition in order to justify the capital cost of equipment. This repetition is the significant characteristic of system building technology.

Organization

The direct tender form of organization in traditional building is characterized by almost complete separation of functions. This characteristic is inefficient and not appropriate for high-volume production. The main difference in system building is the grouping of the critical functions of the building process into an integrated organization under a sponsor's leadership.

Management

The limited management skills required in traditional building are concerned with on-site activities, production and scheduling. In system building, such factors as large capital investment, difficult marketing problems and the need for financial planning, call for management skills of considerably greater sophistication.

ONTARIO'S HOUSING INDUSTRY HAS MANY SYSTEMS CHARACTERISTICS

Ontario's conventional housing industry has advanced a long way from the "traditional" types of technology, organization and management described above. In many respects it has already progressed to a system-like approach.

Standardization of Technology

Segments of the Ontario housing industry have adopted some aspects of system building technology:

- Standardized design: This standardization is most apparent in the multi-storey apartment buildings of some major Ontario development companies. Structural form is quite similar from building to building with differences limited to slight variations in thickness and span of floor slabs, or the size of vertical load-carrying members. Components such as partitions, kitchens and bathrooms have evolved to standard or near standard design, as have jointing details. Similarly, the single-family tract builder has also evolved into more standardized design. Most subdivisions, particularly those aimed at middle income purchasers, employ relatively few designs scattered around the site in such a way as to avoid obvious repetition.

  The move towards a greater degree of standardization in conventional building has been largely motivated by the desire to achieve economies of scale which repetition promises, combined with the realization that the infinite variety which characterized the older traditional industry is not really needed. Good designers have found that aesthetic and functional quality can still be achieved within a more realistic assessment of the cost/benefit trade-offs attributable to industrialization.

- Factory-produced components: Along with increased standardization of designs, the conventional building industry has also increased the amount of prefabrication of components, thereby reducing the amount of site activity.

There is some prefabrication of plumbing, partitioning, cladding and other components including the prefabrication of walls and roofs by some single-family home builders. The major aspect of apartment building not yet prefabricated is the building structure.

- Repetitive site processes: Apartment builders with flying forms and closely controlled construction sequences have developed a very efficient "factory" process. Similarly, builders of tract housing using an assembly line method with crews moving from building to building in successive finishing operations have developed a semi-industrialized approach.

Therefore, the primary difference between system building and the conventional building technology as we know it currently in Ontario is that system building starts first with standardization and factory manufacture of major structural components. While it has developed many forms of standardized designs and components, factory manufacture of structural components is largely absent from the conventional housing industry.

Integrated Organizations

Here again the conventional building industry has developed a more systems-like approach. Integrated organizations account for the bulk of housing production.

- Own/design/build: This is the typical organization of a large Ontario development company. The owner/developer employs labour directly or subcontracts to associated building companies. Many employ their own architectural staffs, or at least an independent firm on a continuing

basis. In this manner a developer can achieve very close coordination between the own/design/build functions. Combined with volume purchasing of materials and minor components he can achieve some economies of scale and provide for overall project control.

- Design/Build: This organization is common in both housing and industrial buildings. Companies offer package or turnkey projects to owners and perform both design and construction under the control of a single organization. This organizational form is aimed at efficiency and cost control and also serves as the basis for the builder proposal technique used by OHC.

Again, the conventional building industry in Ontario has progressed into organizational forms with some similarity to those used by system building. The primary difference is that major capital-intensive facilities are largely absent from these integrated organizations. Instead, builders and developers purchase components from existing manufacturers outside their organization.

Advanced Management

In the conventional building industry as we know it in Ontario, there are areas where management problems are considerably more complex than those described earlier for basic traditional building.

- Building product manufacturing: Regardless of the product, this industry has most of the management problems common to any manufacturer and the system builder. Capital investment is large, products must be marketed and sold through sales organizations, production and delivery schedules must be met, long-term planning is needed.

- Land and housing development: The more integrated forms of conventional building organizations, such as developer/ builder, have considerably greater management requirements than in traditional building. In the housing field the owner/builder must have sound marketing and finance capabilities as well as tight project control and overall property management skills.

The differences in management skill requirements between these segments of the conventional industry and those required in system building are matters of degree and emphasis. Probably the major difference lies in marketing. The system builder faces a more difficult marketing task than, say, a product manufacturer, because of the limited number of clients available to him and the complexity of a total housing "package" when compared to a single minor component product. While his investment may not be as large, his factory scheduling may be more complex because of the large size of each order (if he has a multi-storey system) and his inability to manufacture for inventory.

MAJOR COMPONENT USE COULD INCREASE INDUSTRIALIZATION

As noted above, industrialized production of secondary components is increasing productivity in the conventional industry and reducing on-site construction time. The increased use of more complex components is a trend that, if encouraged, could lead to further increases in productivity and the benefits of industrialization.

At the beginning of this Part, we discussed the system approach and how system building was an application of this approach to the building process. In fact, other solutions could result. One of these, which could be called "component building", would enlarge on the present trend to capitalize on the conventional industry and seek to develop greater use of more complex, factory-produced components such as complete interior and exterior wall assemblies, kitchen and bathroom core units, plumbing and heating systems, etc. These components would resemble the sub-systems used in advanced building systems, but need not be tied to the marketing restrictions of a single building system. In fact, major components could be used by both system and conventional industries alike.

We believe that there are sound reasons for encouraging a more component-oriented approach. We will examine this in more detail in Part 3 when we discuss the opportunity for system building in Ontario.

2

SYSTEM BUILDING IN OTHER COUNTRIES

System Building is essentially a post World War II European development. In this Part we shall examine the underlying reasons for its development, the factors that contributed to its success and the problems it has encountered, as a basis for determining its usefulness in contributing to the solution of Ontario's housing problems.

Chapter I traces the beginnings of system building in Northern and Eastern Europe and analyses the problems it was designed to overcome. Since system building's success is highly correlated with government participation in housing, Chapter 2 examines governments' role, with particular emphasis on the kinds of activities undertaken and the direct support provided. Chapter 3 reviews developments to date, focusing on system building's success or otherwise in solving the problems it was designed to deal with. Finally, since the housing industry in the U.S. resembles that in Ontario, we examine developments there and provide some background to the recent attention being given to system building.

REASONS FOR DEVELOPMENT 2·1

System building as we know it today developed in Northern and Eastern Europe following World War II, because the industrialization of the building process offered a means of solving two key postwar problems faced by those countries - a huge shortage of housing and a scarcity of skilled labour. It is important to note that cost reduction was not a primary reason for its development.

HOUSING SHORTAGES A RESULT OF MANY FACTORS

Wartime destruction was, of course, one of the reasons for the severe shortage of housing that existed immediately following the war, but there were others, including a scarcity of labour and materials; the virtual cessation of housing construction throughout the war years; increased demand as a result of rising affluence; a jump in household formations; migration; and rising birthrates.

Wartime Destruction

During World War II, a vast amount of housing was destroyed. In Europe (excluding Russia and Germany), 5.7 million units were totally or partially destroyed, and a further 8.9 million were slightly damaged. In Russia and West Germany

alone, more than 30 million homes were destroyed or damaged. Overall, some 4% of pre-war European housing was completely destroyed.[6*] With the addition of the work needed to repair damaged dwellings, the overall backlog amounted to the equivalent of six years' housing construction at the average pre-war rates.

In those countries directly involved in the war the loss of housing was heavy. Expressed as a percentage of total pre-war housing stocks, Yugoslavia lost 25% of its housing; Poland 22%; Greece 21%; West Germany 22%; Russia 25-30%.[6] The losses were heavy, too, in terms of the industry's production capability. In Poland, for example, wartime destruction was equal to about 15 years' production at the pre-war rate of building.[72]

Lack of Building Construction

House building, maintenance and repairs virtually ceased during the war years. Even Sweden, which was not directly involved in the war and had none of its housing destroyed, experienced a sharp decrease in housing production during the war years. Had production in that country continued at pre-war rates, there would have been 150,000 more dwelling units at the end of the war than there actually were.[72]

Moreover, in most European countries large scale housing programs were not commenced immediately following the war because for economic reasons, other kinds of construction assumed higher priority. Production at that time was obviously inadequate - even present building rates have not succeeded in eliminating the shortage (Table 2.1). It was not until almost 1950 that most countries made their first post-war housing and

**For References see Appendix D*

TABLE 2.1

MOST EUROPEAN COUNTRIES HAD A LOW RATE OF HOUSING PRODUCTION UNTIL THE MID-FIFTIES

HOUSING COMPLETIONS PER 1,000 POPULATION

	1949	1956	1968
CZECHOSLOVAKIA	2.4	5.1	6.0
DENMARK	5.9	4.4	9.2
FRANCE	1.4	5.3	8.2
NETHERLANDS	4.9	6.4	9.7
POLAND	2.4	3.2	5.9
SWEDEN	6.0	7.8	13.2
UNITED KINGDOM	4.4	6.0	7.8
U.S.S.R.	-	7.9	9.4
WEST GERMANY	4.5	11.2	9.4

Source: Refs. 2,6

population census, and it was generally not until the mid '50s that housing production began to close the gap between supply and demand.

Scarcity of Building Materials

Immediately following the war, housing production was held up by lack of materials, brought about by the postwar construction priorities.already referred to. The socialist countries of eastern Europe, for example, entered a period of rapid industrialization after the war. Their governments and that of France gave investment priority to construction for industry. These and other programs consumed great quantities of steel and cement that could have otherwise been used for housing.

Post-war Demographic Factors

There were sharp changes in domographic patterns following the war. Demobilization of the armed forces set off a sudden increase in family formations. This and the resulting post-war baby boom greatly increased the need for more housing. The concentration of industrial reconstruction brought huge numbers of workers to the major cities, where the housing shortage was particularly acute. The pressure was increased by declining mortality, and "undoubling" of larger households as members of the younger generation tried to establish households of their own. And as economies expanded, people demanded better quality housing.

LABOUR SHORTAGE WAS THE OTHER KEY PROBLEM

Wartime casulaties seriously reduced Europe's construction labour force but the situation was compounded by other factors. Those young men who in peacetime would have apprenticed to the construction industry had become members of the armed forces, which resulted in a serious shortage of skilled workers after the war.

The supply of labour for housing construction was further diminished by national economic recovery programmes. The higher priorities set for capital goods and export industries channelled labour away from housing into industrial plants. In the process, construction workers developed new skills and left the building industry for good.

By the late 40s and early 50s labour shortages throughout Europe had reached the point where the huge, accumulating demands for housing could not possibly be satisfied - at least by conventional building methods.

SYSTEM BUILDING OFFERED A SOLUTION

In the face of the problems outlined above, some industrialization of the building process seemed to be the only way that inroads could be made on the huge backlog of housing demand. Attempts had been made previously at prefabrication, but the extreme shortages of the postwar period finally provided the impetus for the development of large-panel building systems.

The prefabrication of structural and other elements in enclosed conditions saved time and avoided delays due to bad weather, an important consideration in Northern Europe. Another important factor was that a high percentage of the site work could be done with unskilled labour.

COST REDUCTION WAS NOT A MOTIVE

It is very important to note that in the introduction and early development of system building in Europe, cost-saving considerations played little or no part. On the contrary, the governments involved often took the view that it was worthwhile to subsidize system building because it provided a solution to other problems which were seen as more pressing.

THE ROLE OF GOVERNMENT 2·2

Governments have played a vital role in system building in all those countries where this form of construction is advanced. This includes most of the countries of Northern and Eastern Europe - particularly some of the communist countries. In fact, there tends to be a close relationship between the extent of government participation and the degree of development of system building. The magnitude of the housing problem in these countries, coupled with the lack of sophistication of the conventional construction industry prompted governments to take the initiative in housing and develop policies to encourage system building.

In short, governments decided to assume a larger share of the responsibility for housing. In practice this meant the organization and management of housing programs and the allocation of the limited supplies of capital, materials and manpower to reconstruction.

But governments not only assumed control of production, they also adopted comprehensive housing policies for planning, production and distribution of housing. Specifically this involved:

- Projecting total housing requirements;
- Setting and up-dating short and medium range volume targets;
- Ensuring the availability of funds to meet programs based on the above targets;

- Relating production and distribution to national goals in other sectors of the economy;
- Controlling total housing stock distribution;
- Improving the technology, organization and management of the building industry.

The extent to which governments assumed control varied by country, of course, but this list indicates the scope of state control.

GOVERNMENT INVOLVEMENT PROVIDED REQUIREMENTS FOR SUCCESS

Government played a vital role in the development of system building because of its ability to provide the conditions needed for the new building process to succeed. Specifically, governments ensured:

1) Continuous demand;
2) Standardization;
3) Research and development in building technology.

GOVERNMENT COMMITMENT ENSURED CONTINUOUS DEMAND

Large scale continuous demand is vital to successful system building. Governments, by virtue of their involvement and scale of operations, had both the resources and the power to push system building development. This was most apparent in the more socialistic countries. However, commitment in principal rather than actual direct involvement seems to be the major factor. In Sweden, for example, despite the fact that the government is responsible for providing over 60% of all housing, system building has not done so well as it has in Denmark, which has less government

involvement but where the state has made a strong commitment, with the result that system building accounts for over 60% of all housing. Generally speaking, the communist countries have made the heaviest commitment and since the governments of these countries provide virtually all the housing, there is a very high penetration of system building (Figure 2.1).

Governments have provided continuous demand in four important ways:

a) Developing long-range housing plans;
b) Adopting land policies that have guaranteed the availability of economic housing sites;
c) Ensuring availability of funds to support housing programs;
d) Commissioning large-scale system building programs.

SYSTEM BUILDING IS MOST ADVANCED IN COUNTRIES WHERE THE PUBLIC SECTOR PLAYS AN ACTIVE ROLE IN HOUSING

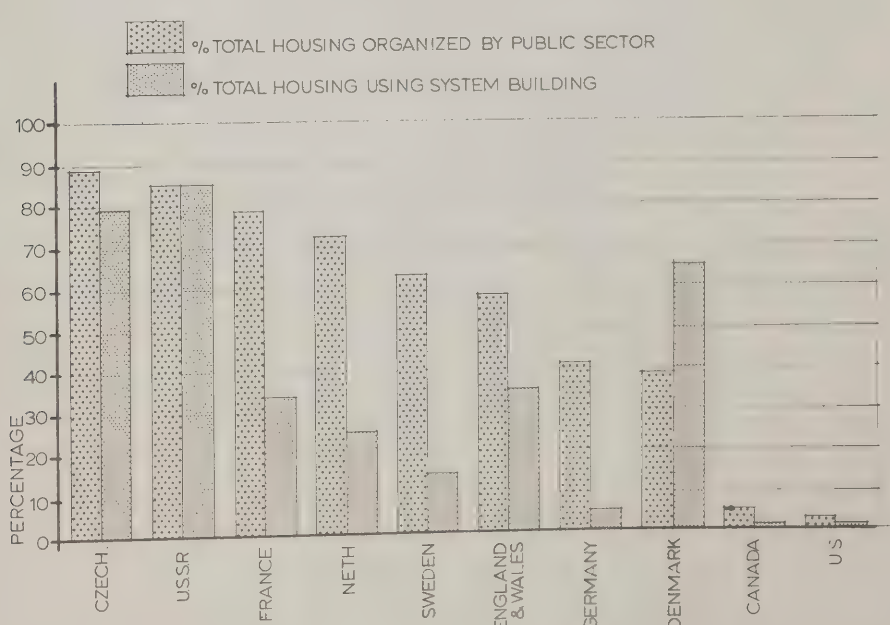


FIG.2.1 1967-68

Source: Refs. 2, 19, 29, Peter Barnard Assoc.

Long-Range Planning

The development by most European countries of national housing plans with detailed year-by-year targets made a valuable contribution to system building. Since the governments had the power to carry out their plans, the system builder could invest in capital-intensive facilities and be assured that demand would be maintained at a relatively high level despite changes in the economic climate that typically play havoc with housing demand.

Land Policies

Government involvement in land development became widespread following World War II, and in the late '50s and early '60s government commissions examined the best ways to control land. Basically, there have been three methods used: 1) advance purchase, 2) price controls and 3) land taxes.

Advance purchase or land banking ensures that the value added to land due to nearby development accrues to the public. By 1925, Denmark, Britain, The Netherlands, Germany, Poland, Czechoslovakia and France had been assembling land that was subsequently made available at below-market prices. Today some governments lease publicly assembled land to private builders, others sell it. Price controls relate to determining rents and land selling prices. Land taxation, the other main method used to control land, includes such techniques as value-added taxes on improvements, betterment levies, site value taxation and various forms of capital gains tax.

Financial Policy

Financial and tax policies have helped ensure adequate capital to meet housing program targets. In some countries, governments have access to savings funds for building construction. A major strength of most housing cooperatives, societies or associations is the compulsory members' savings plan - a source of funds for housing. The Swedish government taxes the home building industry at the rate of 0.4% of wages to pay for housing research.

Large-Scale Programs

Probably the most important single factor in the development of system building in other countries has been the scale of government housing programs. Contracts typically cover 3 to 5 years and 1,000 to 2,000 units or more. In France, some 20 system builders were allocated 25,000 units per year of government housing. Several other governments have reserved specific parts of their housing program or earmarked specific projects for system building. As one example, the Danish government specified in 1960 that 2,000 units per year for 3 years would be built.

STANDARDIZATION PLAYED AN IMPORTANT PART

The standardization of dimensions, components, plans and codes made a major contribution to the successful development of system building. By limiting haphazard and unnecessary variety, production costs were decreased and productivity was improved (Figures 2.2 and 2.3). Without government encouragement and control of standardization, system building would have been unable to realize all the benefits of industrialization.

STANDARDIZATION LEADS TO DECREASED PRODUCTION COSTS

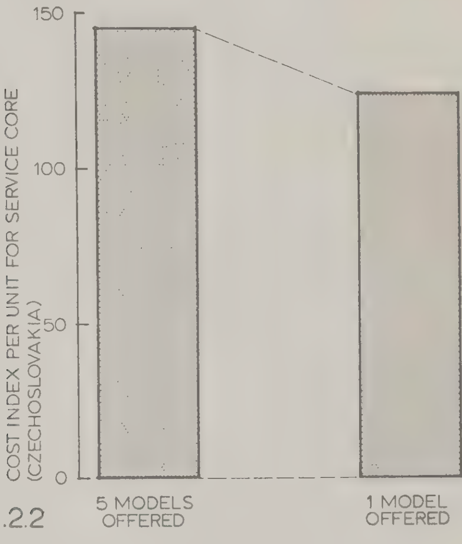


FIG.2.2

Source: Ref. 3

STANDARDIZATION PERMITS INCREASED PRODUCTIVITY

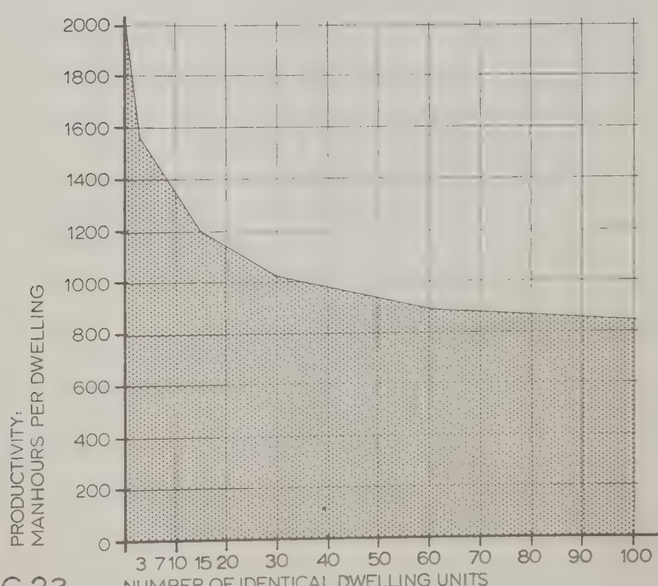


FIG.2.3

Source: Ref. 4

Governments and some housing cooperatives initiated size and detail standardization. Most European countries now build on a 100-millimeter (approximately 4 inches) module which facilitates import and export of building components. In France, the State Secretariat for Housing established standards for such components as partition walls, kitchen equipment, entrance doors and light fixtures to encourage mass production. The Swedish housing cooperative HSB has its own component plants for the 15,000-18,000 units it builds each year.

Standard plans have been developed, especially by those countries where system building is most highly developed. Standard plans may be mandatory, (type plans) or for guidance only (model plans). However, when used to extreme, as in Russia and Czechoslovakia, standard plans can produce monotonous results.

RESEARCH AND DEVELOPMENT IS ANOTHER IMPORTANT GOVERNMENT FUNCTION

Responsibility for research and development was undertaken by government because the building industry itself was too fragmented to do so. Technological and organizational research were vital to the progress of the new industrialized building systems.

Besides doing research in building techniques and other areas directly related to system building, government agencies continue to carry out a great deal of work in related fields such as financial policies, building regulations, urban design methods and city planning, all of which can contribute to better uses of system building.

For example, there have been studies of long and short-range demand. Britain, Russia, Czechoslovakia and Sweden are among the countries that establish annual housing programs up to 7 years ahead. The Swedish government requests municipalities to prepare 5-year rolling plans which are updated each year. This enables a longer-range view of labour and investment requirements.

Housing requirements change with changes in life style patterns. User needs studies are being undertaken in many countries in order to relate mass housing production to real and not imagined or outdated requirements. Several national building research institutes, such as those in Britain and Sweden, are also studying site processes where both conventional and system building are employed. Several European countries have sponsored independent agrement boards to test and approve new materials and components. In the U.K. the government is instituting industry-wide dimensional coordination which will help increase interchangeability of large components made by different manufacturers.

The Czechoslovakian government designs, develops and tests housing layouts which are then used for mass-produced system-built housing. This is done on a 5-year cycle to keep the designs under constant review.

DEVELOPMENT TO DATE AND CURRENT STATUS 2·3

System building has developed rapidly over the past 15 or 20 years, and the pace is accelerating with recent increased interest stimulated by developments in the United States. Thus, any review of the current status is likely to be obsolete as soon as it is completed. Nevertheless some trends have been clearly established.

SYSTEM BUILDING HAS HELPED SOLVE SOME PRIMARY PROBLEMS

System building has been successful in at least two ways: it has speeded-up housing construction and has helped overcome labour shortages. Its impact on construction costs however, has been mixed.

Improved Productivity

System building has generally reduced on-site construction time (Table 2.2), although its success in this area has to be measured against a conventional building industry that was very primitive in post-war Europe compared to its counterpart in Canada today.

Easing of Labour Shortages

With system building, site work is reduced to essentially an assembly task, and skilled labour is concentrated in controlled plant conditions where it can be

TABLE 2.2

SYSTEM BUILDING HAS REDUCED CONSTRUCTION TIMES

COUNTRY	REPORTED REDUCTION IN ON-SITE CONSTRUCTION TIME
U.S.S.R.	50%
CZECHOSLOVAKIA	75%
UNITED KINGDOM	17-50%
SWITZERLAND	75%
DENMARK	65%

Source: Refs. 10, 19 Peter Barnard Assoc.

most effective. Mechanization of in-plant operations has greatly reduced the number of man hours required per dwelling unit (Table 2.3).

Mixed Effects on Costs

Early efforts at system building actually increased costs over conventional building (which was itself a relatively inefficient process at that time). Today, experience has permitted system building to exhibit small cost savings in some countries but the effects are by no means universal (Table 2.4). The higher savings which have been achieved in Eastern Europe are probably due to the wider use of system building there, coupled with the lower standards of

TABLE 2.3

SYSTEM BUILDING HAS IMPROVED PRODUCTIVITY

COUNTRY	REPORTED REDUCTION IN MAN HOURS/DWELLING UNIT
UNITED KINGDOM	UP TO 13%
DENMARK	47%
CZECHOSLOVAKIA	43%
U.S.S.R.	35-40%

Source: Ref. 19

TABLE 2.4

SYSTEM BUILDING HAS HAD A VARIED EFFECT ON COSTS

COUNTRY	REPORTED % REDUCTION IN COSTS DUE TO SYSTEM BUILDING
EASTERN EUROPE	
U.S.S.R.	15
CZECHOSLOVAKIA	15
POLAND	10-17
NORTHERN EUROPE	
SWEDEN	NONE
NORWAY	NONE
DENMARK	0-15
WEST GERMANY	5-12*
FRANCE	0-10
U.K.	5-10*

* HIGH RISE ONLY

Source: Ref. 19

the finished system-built product.

Benefits to Conventional Construction

Competition from system building has resulted in improved conventional building methods, especially in Western Europe (Table 2.5). The productivity of conventional builders has been improved by the introduction of more precise scheduling and the use of mechanical equipment on site. Construction times have been reduced, and conventional construction costs have generally remained competitive with those of system building, particularly in low-rise applications.

SYSTEM TECHNOLOGY IS WELL DEVELOPED

Building system technology has been refined in the past decade.

TABLE 2.5

CONVENTIONAL CONSTRUCTION HAS SHOWN MARKED INCREASES IN PRODUCTIVITY DURING AND AFTER THE INTRODUCTION OF SYSTEM BUILDING

COUNTRY	TIME PERIOD	MAN HOURS SAVING
FRANCE	1950-1964	50% (PER D.U.)
WEST GERMANY	1953-1962	38% (PER SQ.M.)
POLAND	1961-1965	6% (PER CU.M.)
DENMARK	1955-1967	16% (PER SQ.FT.)
SWITZERLAND	1958-1967	13% (PER SQ.FT.)

Source: Ref. 19

Early Technical Problems Overcome

Many of the early problems with building systems related to jointing. It was difficult to produce weatherproof joints between mass-produced panels, while wide tolerances made insertion of window units difficult. Faulty panels sometimes resulted in cracks. The esthetic qualities of the early buildings were unsatisfactory because at first architects were only marginally involved in system building. User needs were not carefully enough considered, with the result that buildings were often little more than very basic shelter.

Today, these problems have generally been overcome. Quality control is high, jointing is easily made weatherproof and designers are now more closely involved, even being engaged in sponsorship. More attention has been paid to user needs and plans are continually being refined.

Increased Versatility

The variety of dwelling unit types to which a given building system can be applied has become important. Early systems were designed primarily for medium- and high-rise housing, but today there is an increasing emphasis on low-rise and mixed high- and low-rise projects. Many of the systems have proved to be adaptable to this trend (although there has been some difficulty in standardizing the structure for both high-rise and low-rise loads).

High-Rise Panel Systems Dominate

Large concrete panel systems dominate the high-rise apartment market which accounts for the great majority

of system building. Among the best-known European large concrete panel systems are those of Wates, Camus, Balency, Larsen Nielsen and Jespersen. Box systems are being used in Russia and Czechoslovakia, while frame systems are confined mainly to a small segment of the low-rise market.

Differences between the large panel building systems are small and usually occur in jointing technology. Most concentrate on factory production of structural wall and floor panels but many include other elements such as stair shafts, balconies and cladding. Some systems have developed their own "wet core" units or incorporate plumbing trees in panels.

Concentration on large panel systems has produced some highly sophisticated production methods. Panels can now be formed with intricate cut-outs and lips, and molds can be placed in horizontal or vertical batteries. Some plants are highly automatic with only a handful of men needed to produce panels for 1,500 units per year. Pouring, curing and removal from molds has been reduced to 4 hours in some systems.

Greater Variety in Low-Rise

European low-rise systems show a great variety in technology and appearance. A possible reason is their closer affinity to traditional housing forms, where people have come to expect more variety. Panel systems predominate, with some use made of frames. Materials used include wood, concrete and brick. Generally there is less prefabrication than in high-rise systems and plant production methods are less advanced.

The low-rise systems have generally not been able to compete with conventional construction in Britain and Scandinavia, except where they have been designed in conjunction with high-rise units. Nevertheless, building systems have been used for low-rise units from one-storey garden-court houses to three-storey terrace units. Moreover, in terms of numbers of systems in production, there is a definite trend toward the development of low-rise systems (Figure 2.4).

MARKET PENETRATION IS VARIED

System building's share of the housing market varies widely from country to country and the concept is being introduced to more countries. Panel systems are most popular and trends indicate there will be increased development of low-rise systems in the future.

IN TERMS OF NUMBERS OF SYSTEMS IN PRODUCTION THERE IS A DEFINITE TREND TOWARDS LOW RISE SYSTEMS

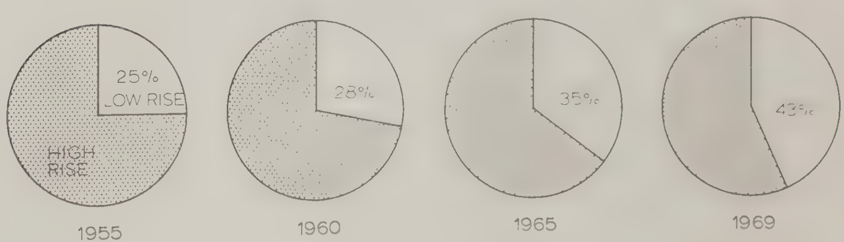


FIG. 2.4

Source: Ref. 5 1

Varied Penetration

As discussed in the previous Chapter, the greatest development of system building has taken place in those countries where there is greater state control of the economy. As noted earlier, this is because many governments in Europe maintain control over housing and have demonstrated a commitment to system building.

In France and Denmark, central control is also a factor, but in other highly-industrialized countries it appears that conventional construction remains competitive with system building and the latter's penetration is small. It should be noted that statistics relating to building systems may be misleading, because the extent of prefabrication is not well defined.

Expansion to Other Countries

Serious efforts to develop system building can be observed in many other countries, including Australia, South Africa, Israel, Switzerland, Italy, Japan, Canada and the United States. In Italy and South Africa, the labour and housing shortages in certain key urban areas has provided the impetus, while in other countries the motivation has been a general housing shortage. In most cases the initial adoption of system building is affected by the importing of technical and management expertise from advanced system building countries on the basis of a licencing or equity arrangement. Both the United States and Canada have seen concentrated efforts to set up imported building systems in major market areas. Modifications are made to suit local user needs and industry practices, but the necessary experience and plant equipment designs come from the parent company. The expansion of European system

builders throughout the world has led to the development of international firms with large production capabilities (Table 2.6).

SYSTEM BUILDING STILL EXHIBITS SOME PROBLEMS

Because of a continuing housing shortage, emphasis in eastern Europe has remained on high-volume production at the expense of design developments. Space standards and finishing quality are low and monotony is a problem, not only with individual buildings, but for whole neighbourhoods because of over-standardization. A similar esthetic problem occurs occasionally in Western Europe as well, but there sponsors and clients have generally realized the need to allow some design freedom, with choices of materials, finishes, colours and form.

TABLE 2.6

THERE ARE SYSTEM COMPANIES WITH MANY INTERNATIONAL LICENCEES AND LARGE PRODUCTION CAPABILITIES

SYSTEM	COUNTRY	NUMBER OF FOREIGN LICENCEES 1969	NUMBER OF UNITS BUILT TO DATE 1969
LARSEN & NEILSEN	DENMARK	11	67,000
BOUWVLIET	NETHERLANDS	8	*
CAMUS	FRANCE	7	155,600
SECTRA	FRANCE	7	10,900
SKARNE	SWEDEN	6	35,800
BALENCY	FRANCE	6	*

*Figures not available

Source: Ref. 51

British Marketing Problems

System building in Britain is an example of too many producers in a limited market. Government endorsement of system building as part of an election compaign in 1964 precipitated the introduction of more than 300 systems. Today only a few of these are competitive (Table 2.7). The majority are caught in a vicious circle: they are not price competitive, so they do not get experience on contracts large enough to develop economies of scale.

In addition, strong negative public reaction followed the partial collapse of an apartment building using a known and tried system at Ronan Point, London. The building suffered progressive collapse following a gas explosion caused by a faulty plumbing connection. The repercussions were sufficiently severe to adversely affect the whole system building industry in the U.K. The doubts created in the minds of public officials combined with questions concerning

TABLE 2.7

IN THE U.K. A FEW OF THE MANY SYSTEMS AVAILABLE HAVE THE MAJOR PROPORTION OF THE MARKET

OF ALL PUBLIC SECTOR SYSTEM-BUILT HOUSING:

6 MAJOR SYSTEMS ACCOUNTED FOR 42%

12 OTHER SYSTEMS ACCOUNTED FOR 25%

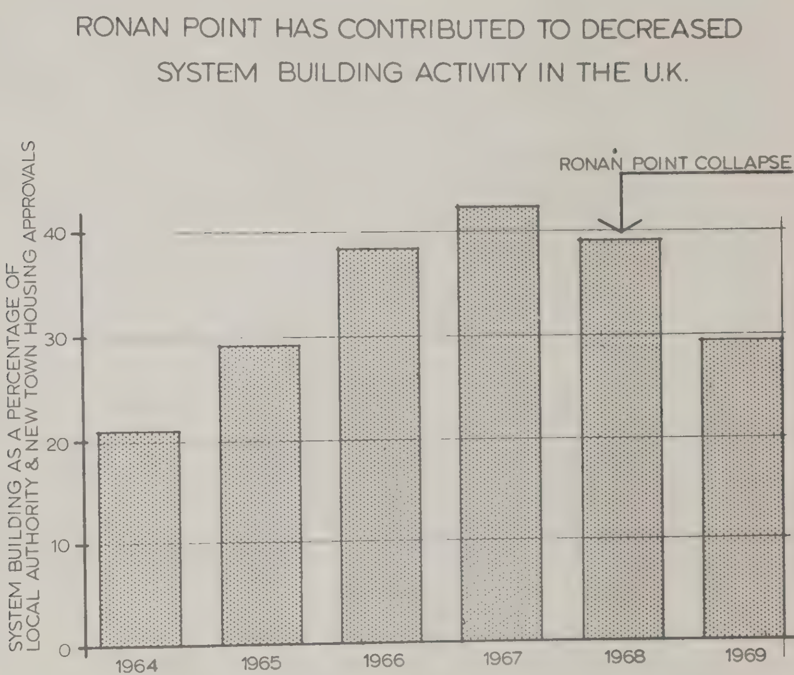
91 OTHER SYSTEMS ACCOUNTED FOR 29%

ALL OTHER SYSTEMS ACCOUNTED FOR 4% +

+ AS HIGH AS 200 OTHER SYSTEMS REPORTED

Source: Ref. 29

the social acceptability of apartments for families substantially reduced demand for system-built apartments (Figure 2.5).



Source: Ref. 26

FIG.2.5

DEVELOPMENTS IN THE UNITED STATES 2·4

The U.S. government's widely-publicized "Operation Breakthrough" (described later in this Chapter) has recently stimulated much interest and activity in system building in that country. Ontario's proximity to the United States and the similarities between the province's housing industry and that of the U.S. make developments there of particular concern.

THE U.S. FACES A HOUSING CRISIS

The United States is faced with a housing crisis brought on by a growing shortage of housing and increasing costs that have made housing unavailable to a large segment of the population.

Accumulating Housing Shortages

Despite the rapid increase in family formations and the need for replacement of substandard housing in the large urban centres, housing production in the U.S. has remained relatively constant at about 1.5 million units per year for the last 2 or 3 years, the same level that prevailed during the mid-sixties. Two independent studies have indicated that the U.S. must build and rehabilitate 26 million houses and apartments during the next decade to provide for new household formations, to allow enough vacancies for an increasingly mobile population, to replace houses destroyed

or demolished and to eliminate substandard housing.[22] This will require an average production of 2.6 million units per year. The current 1.5 million level falls well short of this and serious shortages are accumulating.

High Housing Costs

The housing crisis is caused by a number of factors that together have put the cost of housing well beyond the reach of middle- and lower-income families - the group in most serious need of housing.

A principal cause of both the shortage and cost of housing has been the cost and availability of money. Long-term housing mortgages have traditionally been among the least attractive to the private money markets on which housing activity depends. Thus, in periods of tight money, the flow of funds into housing has fallen off dramatically. Added to this is the fact that over the past few years, interest rates have risen over 50% from the 6% level of 1966 to over 9% in 1969.

A second contributing factor to the housing crisis has been the cost and availability of land. The pressure of increasing population on the limited supply of land around the major urban centres has made land the most inflationary aspect of housing costs. In 1958, land accounted for 10-12% of the sale price of a typical house; it now accounts for over 25%, with little indication of a levelling off.[21,22]

Increases in materials and labour costs have aggravated the problem. Between 1958 and 1968, overall construction costs increased 26% compared to a 20% increase in consumer prices over the same period. Labour wage rates

accounted for the main increase, with a jump of more than 50%.[22] Materials have risen less, although recent increases in lumber and plywood indicate that a faster rate of increase can be expected in the future.

THE INDUSTRY IS INCAPABLE OF MEETING NEEDS

More serious than the existing housing shortage is the problem of meeting needs in the future. Because of the nature of the building industry and the constraints on it, it is very doubtful that improvements can be implemented fast enough to meet the increased levels of production needed to overcome backlogs and growing demand.

Fragmented Industry

The U.S. construction industry is fragmented. The average U.S. builder produces between 5 and 25 units per year and 61% have fewer than 4 salaried employees, according to a survey taken by the National Association of Home Builders.[22] Moreover, these builders cover small geographic areas, for the survey showed that 45% of the firms questioned limited their operations to one county and another 23% operated in only two counties.

In addition, the segmented organization of the building process compounds the problem of introducing new technology needed to increase production. The traditional building process in the U.S. involves the interaction of a variety of participants, none of whom have responsibility for the total process. Since change depends on co-operation and acceptance, the combination of an industry fragmented by size and geography and also segmented by functions makes large-scale volume production extremely difficult to attain.

Labour Shortages

A major constraint on the industry's capacity to meet demand over the next decade is the critical shortage of skilled labour. A recent report published by the U.S. Department of Commerce states that the housing industry presently employs about 1.5 million men. Assuming no major change in building methods, the number of men required will be proportional to volume. Thus, the 66% increase in production needed to reach 2.6 million units per year will require a commensurate increase in the number of men or an additional 1 million men. Moreover, since the ratio of skilled to unskilled is about 2:1, this means that the industry will have to attract an additional 660,000 skilled tradesmen - a difficult task indeed.[22]

A further indication of the impending shortage of construction labour is the average age of workers in the industry. The same study shows that the average is over 40 (in some areas, well over). This is surprisingly high for an industry which involves heavy manual work in sometimes hazardous conditions.

PAST EFFORTS AT INDUSTRIALIZATION HAVE BEEN DISAPPOINTING

Much of the industrialization in the U.S. building industry has been confined to attempts at prefabrication. The fact that these efforts have been primarily concerned with technology probably explains the lack of progress in the important facets of management.

Early Prefabrication

During the early '30s, in the depths of the depression, private and government research efforts were directed

at prefabrication of housing as a solution not to a shortage of housing but to solving unemployment problems. It was thought that providing cheap housing would stimulate demand. The major participants in this venture were The Tennessee Valley Authority, which developed sectional homes for its construction workers, and private companies such as U.S. Steel, American Car and Foundry Co., Pullman Standard Car Manufacturing Co., and General House Inc., who developed a detached house that could be assembled from standard parts. None of these was successful.

During the early '40s, prefabrication was used to provide desperately needed war-time housing in the face of labour and material shortages. From 1940 to 1941, the number of firms involved in prefabricated housing jumped from 30 to 100. Over the war years, over 900,000 units (12.5% of all production) was prefabricated.[74]

Following the end of World War II, the U.S. government extended wartime controls to meet the housing shortages that had accumulated during the war years. The Veterans Emergency Housing Act guaranteed markets for materials and prefabricated homes. In addition, new housing enterprises could be financed under Reconstruction Finance Corporation loans. The Lustron Company was one of the most famous government-sponsored enterprises for mass-production of housing. It built an eight-mile assembly line in a former aircraft manufacturing plant. This and other attempts at mass-production was unsuccessful and by 1948, only 6 of the 42 companies that had guaranteed government contracts were still in business.

Recent Developments

Since the early 1950's, developments have been more evolutionary and more successful. The mobile home industry, for example, has successfully introduced industrialization, largely due to its similarity to the automotive industry. In 1967, mobile homes accounted for 12% of all new housing; by 1969, their share of the market had risen to 28%.[20,22]

Some builders have also made progress in industrialization through the use of pre-cut lumber and automated assembly. The sectional home industry has also advanced in recent years.

Even in the past, technology has typically been adequate. Problems have been in organization and management, but these more recent developments and successes have - in contrast to earlier efforts - concentrated more on those two important aspects.

THE UNDERLYING PROBLEM WAS WITH ORGANIZATION AND MANAGEMENT

The technical knowledge needed to effectively industrialize housing production exists now and, in fact, has been available for some time. The basic problem has been the organization and management of the various participants involved in the total building process from design to occupancy. Early efforts concentrated solely on the technology without considering and co-ordinating problems related to other aspects of the process.

Neglected Marketing

Prefabricators developed modular dwellings without consideration of user reactions. The resulting buildings

were often standardized to the point that they look identical, and consumers reacted unfavourably. Also, little effort was made to prepare potential buyers for the new developments and they associated lightness of structure with weakness, and speed of construction with short life. The Lustron metal house, for example, was rejected because it did not meet potential customers' concepts of a house (its problems were compounded by another weakness in the distribution system - the lack of trained dealer-erectors).

Lack of Financial Backing

Many early prefabricators built plants with insufficient capital to ensure a worthwhile effort. Often, they did not understand the importance of securing inventory or "bridge" financing (between manufacture and sale of their product). Backers were concerned about long-term performance, were afraid of hidden costs and worried about consumer acceptance. The failure of many prefabrication enterprises added to the problem by causing public skepticism, in turn making markets even more difficult and financial backing more scarce.

For these reasons, much of the innovation by builders has been limited to small changes and improved models of existing products. In fact, there has been no element in the house building industry with sufficient control and motivation to initiate fundamental changes in the fabrication and construction process and to carry them through to the final product. Government, by merely providing some low-income units, has not been effective to the extent that its European counterparts have. Even the support promised by government to housing industrialization immediately following the war, was largely removed three years later.

Now, with the housing shortage and labour scarcity becoming more evident, steps are being taken to gear-up for high volume industrialized production. Some work is being done by individual manufacturers on their own initiative, but the most publicized effort has been "Operation Breakthrough", sponsored by the Department of Housing and Urban Development.

OPERATION BREAKTHROUGH IS AIMED AT STIMULATING INDUSTRIALIZATION

This program, developed during the first half of 1969 by the Department of Housing and Urban Development (HUD), is aimed at overcoming several of the obstacles to higher-volume industrialized house production. By working within existing programs, HUD is searching for new approaches to marketing and construction management and seeks to make maximum use of private initiative.

New Approach

The goal of "Operation Breakthrough" is the establishment of a self-sustaining mechanism for rapid high volume production of marketable housing at progressively lower cost for all income groups. To to this, HUD will draw on the financial resources and powers of its programs for social housing, urban renewal and financial and community development assistance.

In doing this, HUD is looking for new approaches to housing production, financing, marketing, management and land use. It will involve state government in U.S. housing programs to a greater extent than ever before in an effort to overcome the fragmentation of many local market (unlike

the Canadian provinces, the individual States are almost totally un-involved in housing). HUD's commitment is limited to $60 million over the next three years (subject to congressional approval). A similar amount may be borrowed from private mortgage sources.

Maximum Use of Private Initiative

The means used by HUD to carry out its program relate directly to the market-oriented structure of the building industry and impose a minimum of extra cost on the government. HUD began by holding a competition for new ideas related to a combination of technology and management aspects of building. Phase I of Operation Breakthrough consisted of a two-stage competition in two categories:

1. Type A Proposals employed immediately available technology. Over two hundred entries were narrowed down in two stages to 22 finalists. Selected professionals, HUD and other government agencies chose the winning entries. Prior to construction, some of the new systems will be lab tested. A combined group of the National Academies of Science and Engineering has reviewed testing procedures and will examine the measurements made and will certify final results. Much of the actual testing will be done by the National Bureau of Standards. HUD will rely on the experience of FHA and contractors for market acceptability. An assessment of consumer acceptance of the finalized Phase I prototypes will also be carried out. Site selection was accomplished by having municipalities submit potential tracts of land cleared of code

restrictions on factory-type housing, and site planners were chosen. Building system producers will become sub-contractors to site developers.

2. Type B Proposals consisted of advanced technology requiring extensive testing. In addition, entries were permitted for only partial systems consisting of a few major components. HUD has still not selected finalists for this stage.

Phase I will be complete when 1500 units have been constructed using two or three of the Type A building systems on each of 11 sites.

Phase II will consist of on-going efforts by HUD to assemble land and get codes waived in order to facilitate the operations of the conventional building industry.

Emphasis on Innovation

Of the 22 Type A finalists, nearly all represent major departure from current building, either in technology, organization and management, or both. Seven winners are concrete systems, two originated in France, one in England, and another was developed in Canada. Six winners claim the ability to provide all housing types - single family, semi-detached, low, walk-up and high-rise. The single Canadian entry (by Descon/Concordia of Montreal) introduced extensive new management patterns. Because of the extent of innovation, it is not yet certain if all 22 finalists will be able to proceed with prototype design.

Questionable Effectiveness

There are clear indications that Operation Break-

through will not solve the U.S. housing problem. Its budget is very small and subject to curtailment by government. But the main obstacle to the use of system building as the principal solution to the housing problem lies in housing finance and the cost of money, on which it has no effect. Most of the low and middle-income groups cannot afford new housing and builders cannot make a profit in attempting to satisfy this vast segment of the market. Because of its ability to affect only the labour content (and to a small extent the materials content) of costs, it seems that system building will not be an effective substitute for greater government involvement in the provision of housing for low-income families.

SUMMARY AND CONCLUSIONS 2·5

In this Part of the report we have outlined the most important aspects of other countries' experience, emphasizing those areas which are relevant to the development of system building in Ontario.

System building was developed in Northern and Eastern Europe following World War II to deal with two specific problems - a large backlog of demand and a shortage of skilled labour and has generally proved successful in overcoming these problems.

Its success can be largely attributed to strong support by governments assuming a wide-range of powers to back up their responsibility for housing. These governments have provided the driving force behind system building by sponsoring its development and assuring the continuous demand that is the key to its survival. Governments provided further support by developing industry-wide standards for building dimensioning and components, by providing uniform building regulations and by sponsoring research and development into many factors related to system building.

Potential cost reductions were not a primary motive in the development of system building. Cost savings have been modest despite the fact that system building was competing against relatively unsophisticated conventional building industries.

Large panel concrete systems account for the bulk of systems production and have been primarily employed in multi-storey buildings. Many of these systems are being introduced in other countries by licencing.

System building accounts for major proportions of total housing construction in Eastern Europe while in Northern countries penetration seldom exceeds 20% or 30%. The competition introduced by system building has generally resulted in noticeable improvements in productivity and methods by the conventional building industries.

In the U.S. a serious housing shortage is developing: present construction methods and labour supplies appear to be inadequate to meet future requirements. Past experience with highly industrialized housing methods has not been very successful, mainly due to marketing and finance problems. "Operation Breakthrough", sponsored by HUD, is attempting to encourage the formation of new systems and sponsors by aggregating demand and providing research and development funds.

The implications of U.S. experience for Ontario are important, but as we shall show in Part 3, the Ontario situation is significantly different; it corresponds neither to the post-war European environment nor to the present U.S. scene.

The role Ontario Housing Corporation should adopt in the development of system building depends in large measure on the contribution system building can make to the solution of Ontario's housing problems.

In Chapter 1 we shall examine the nature of Ontario's current housing problems and their principal underlying causes. Chapter 2 will focus on the future, forecasting the probable numbers, types and geographical distribution of Ontario's housing needs over the next decade. Against this background we shall, in Chapter 3, analyse and discuss the potential for system building and outline another application of the systems approach that could represent a better solution than system building itself. In Chapter 4 we shall discuss the key requirements for successful system building development and the prospects for meeting these in Ontario. Finally, we shall review some of the constraints and obstacles to be overcome and the impact system building will have on the existing industry.

ONTARIO'S HOUSING PROBLEMS AND THEIR CAUSES 3·1

There is widespread and justified concern about Ontario's housing problem, and while it is frequently called a shortage or backlog of demand, we believe it is placed in truer perspective when it is described in terms of its underlying cause - soaring costs.

HOUSING COSTS HAVE RISEN BEYOND THE MEANS OF THE MAJORITY

This is Ontario's major housing problem - rising costs - particularly in Metropolitan Toronto. The problem has reached the point where acceptable housing is beyond the reach of a majority of the population. And it is important to note that the reasons for the rapid increase in costs are almost all outside the control of the construction industry.

A Measurement of Housing Needs

There is no absolute measure of housing shortage. Virtually everybody has a home of some kind - but practically everybody would like something better than he has or can afford. It can be argued that a housing shortage exists when there is not enough new housing being built to:

1. accommodate the number of new family formations;
2. replace houses destroyed; and
3. effect an overall improvement in the housing stock.

Thus one way to measure the extent of a housing shortage is to relate the production of dwelling units to a basic indicator of need such as net family formation. Based on this method, we have made some estimates of Ontario's housing needs.

Between 1956 and 1965 approximately 1.65 housing units were built for each new family formation. This level of production was sufficient to accommodate new family formations; replacement of substandard housing; progressive undoubling (the process of reducing the number of families living together); and replacement of housing destroyed by highway construction, urban renewal, etc. In other words, the average ratio of 1.65 completions per family formation represented a steady improvement in the housing situation. The state of the existing inventory of housing suggests that this rate should at least be maintained if housing shortages are to be avoided and standards improved.

Declining Completion Ratio

The Ontario housing industry is among the most active in the world, with over 11.0 housing starts per 1,000 population (vs.9.5 for Canada as a whole, and 7.7 for the U.S.) (Table 3.1). But since the mid '60s, housing production in Ontario has not kept pace with the basic demand created by net family formation. While production has increased steadily throughout the '60s and particularly since 1966, net family formations have increased even faster. As a result, the ratio of net family formations to completions dropped to 1.2 in 1967 and has remained well below the 1.65 average since (Figure 3.1).

TABLE 3.1

THE ONTARIO HOUSING INDUSTRY IS AMONG THE MOST ACTIVE IN THE WORLD

COUNTRY	TOTAL STARTS 1968	STARTS PER 1000 POPULATION
SWEDEN	106,700	13.2
ONTARIO	80,400	11.1
NETHERLANDS	127,700	10.0
CANADA	196,900	9.5
U.S.S.R.	2,233,000*	9.4*
WEST GERMANY	542,000*	9.4*
DENMARK	42,800	8.8
FRANCE	434,300	8.5
NORWAY	30,700	8.0
U.S.A.	1,547,000	7.7
UNITED KINGDOM	405,900	7.3

** Completions*

Source: Refs. 2, 24

HOUSING PRODUCTION OVER THE PAST FEW YEARS HAS NOT KEPT PACE WITH BASIC REQUIREMENTS

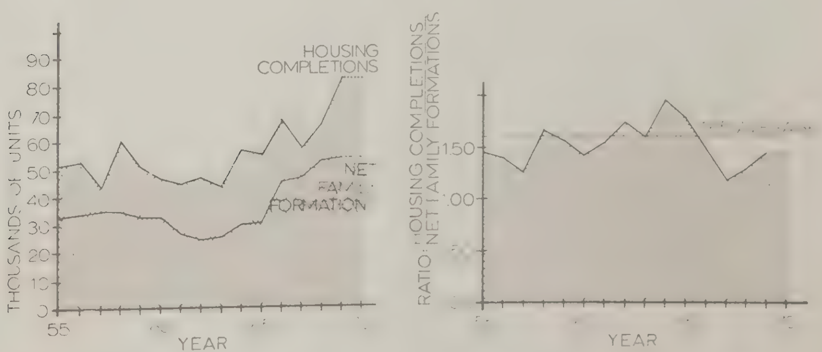


FIG 3.1

Source: Ref. 24, Peter Barnard Assoc.

On this basis, there has been an accumulating shortage of housing in Ontario. The backlog grew from about 7,000 in 1966 to 29,000 in 1967, 46,000 in 1968 and 54,000 in 1969 (Figure 3.2). Compounded by the current building slump, the backlog will probably have risen to 65,000 units by the end of 1970 — to the equivalent of almost a full year's production.

Housing Costs

The traditional rule of thumb is that a family should spend no more than 27% of its monthly income for housing, and that a prospective home buyer should plan to pay no more than 2½ times his annual income for a house. Spending in excess of these limits, particularly for low-income families, is likely to involve sacrificing basic necessities such as health, food or clothing.

SINCE 1966 A BACKLOG OF DEMAND HAS BEEN ACCUMULATING

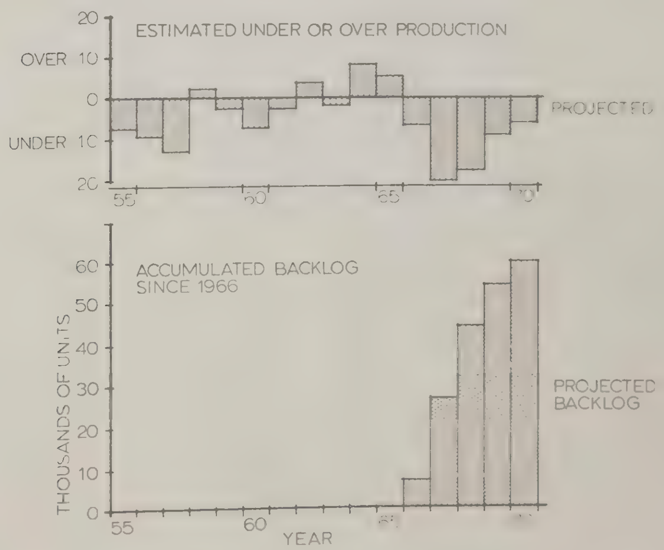


FIG.3.2

Source: Peter Barnard Assoc.

In 1969 the average sale price of a single-family house in Ontario was well over $25,000. To carry such a house would cost over $200 per month - meaning an annual income requirement in excess of $10,000. The median income in Ontario in 1969 was $7,790. Thus, even the middle-income consumer has gradually been eliminated from the new-house market. This is borne out by the fact that the proportion of families of middle income and below qualifying for NHA loans has declined from about 28% in 1967 to 17% in 1969 (Figure 3.3). Despite the indicated housing shortage there are houses vacant and available for sale. As we have already outlined, Ontario's problem is that houses are not being built at prices that those who need them can afford to pay.

FEWER AND FEWER BELOW MEDIAN INCOME
FAMILIES HAVE OBTAINED N.H.A. LOANS

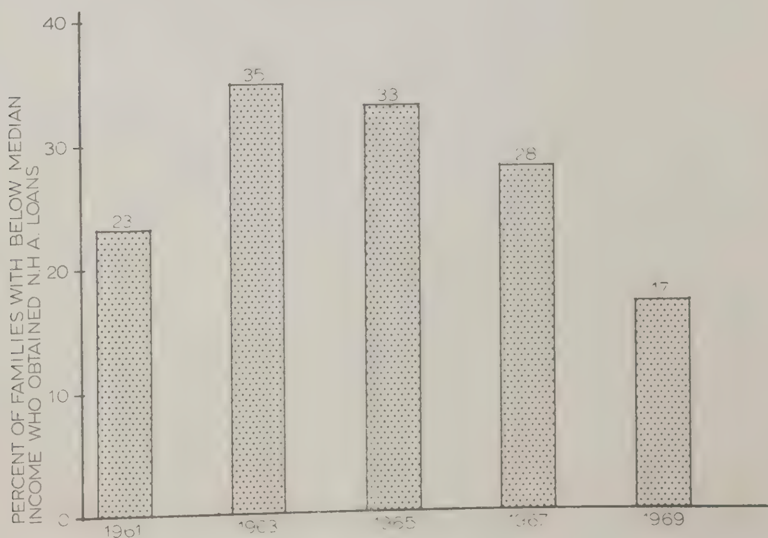


FIG.3.3

Source: Ref. 24

CAUSES ARE DIFFICULT TO OVERCOME

The shortage of housing in Ontario and the rapidly rising costs can be attributed to four major causes:

1. The cost and availability of funds;
2. Availability and cost of land;
3. Cost of construction;
4. Administrative and municipal problems.

These causes are inter-related and, with the exception of the administrative/municipal issues, tied very closely to the overall economy.

Cost and Availability of Funds

Cost and availability of funds is the single most important reason for the wide year-to-year swings in production and the high costs of housing. The housing industry has always been extremely sensitive to national fiscal and monetary policies, and in periods of tight money such as that experienced over the past several months housing starts fall off dramatically (Figure 3.4). Seasonally adjusted housing starts for Canada for the last quarter of 1969 were 183,000 compared to 224,000 for the same period in 1968. The latest available data indicate that the downtrend is continuing in 1970, with starts for the first six months at a level of 160,000.

This sensitivity can be attributed to the heavy dependency on the private money markets for the bulk of financing and the fact that funds are channelled away from housing when other areas of investment become more attractive.

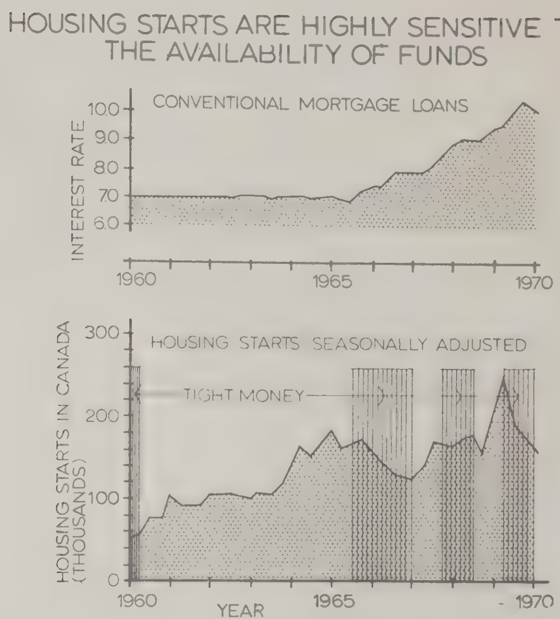


FIG.3.4

Source: Ref. 24, Peter Barnard Assoc.

Long-term housing mortgages have historically been the least attractive to the money market. Furthermore, housing costs are particularly vulnerable to increases in interest rates. Over the past few years interest rates on conventional mortgages increased from about 7% to over 10%, and have had a major impact on costs by increasing the monthly carrying costs of an average $20,000 house by more than 25%.

High Land Costs

A shortage of serviced land at the right price has plagued the housing industry in Ontario since the early '50s. During the past 20 years, building land in Ontario (in particular around Metro Toronto) has soared in price - to the point where it now constitutes a major component of housing costs (Figure 3.5). Considering Canada as a whole, land represented about 10% of the total cost of a NHA home in 1951; by last year it was about 18%. In Ontario the situation is

OVER THE LAST 10 YEARS LAND COSTS HAVE OUTPACED CONSTRUCTION COSTS

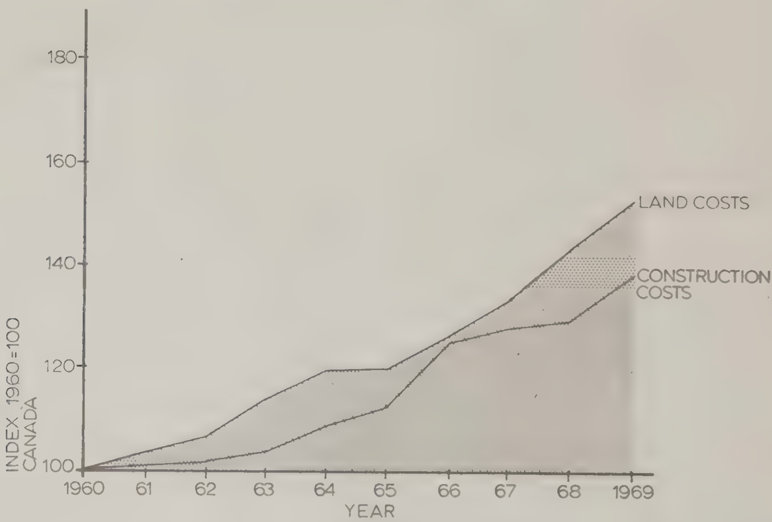


FIG.3.5

Source: Ref. 24.

worse: here land costs, as a proportion of total housing costs, range from 16%-18% in the smaller cities (Barrie, Kingston, Peterborough, Thunder Bay), through 23%-27% in such cities as Kitchener, London and St. Catharines, up to 33% in and around Metro Toronto [24]. Land in the large urban centres has risen to such extravagant levels simply because the pressures of rapid growth in those areas have automatically stimulated great demand.

Construction Costs

Construction costs continue to creep up and are becoming an increasingly difficult problem for the Ontario housing industry.

Construction costs in Canada have gone up over 25% in the last 5 years. In 1965 the average cost per square foot of an NHA-financed bungalow was $11.62; today, 5 years later, the same bungalow would cost $14.62 per square foot - an increase of 26% [24].

The primary cause of the increasing construction costs has been the spiralling wage rates of all types of construction labour, but particularly the unskilled. Over the past 10 years hourly wage rates for residential construction workers have increased over 60% compared to a 25% increase in consumer prices over the same period (Figure 3.6). Truck drivers' and labourers' wage rates increased 70% [24].

The fragmentation of the industry and the resulting inability of the individual builder to resist demands for higher wages has allowed costs to rise rapidly, added to which subcontractors have made little effort to hold down their wages because they have been able to pass on any increases to the builder.

WAGE RATES HAVE INCREASED SHARPLY SINCE 1965

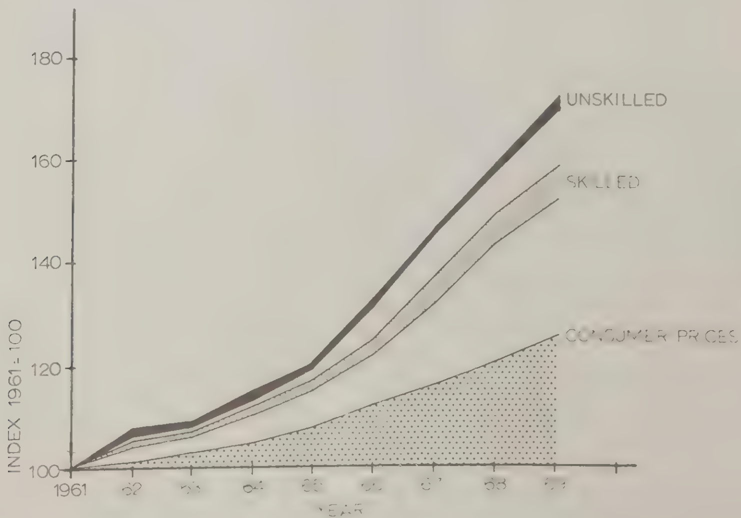


FIG.3.6

Source: Ref. 24

Material costs have also been increasing rapidly. Since 1961 residential building material prices have outpaced price rises in some other segments of the economy (Figure 3.7). Lumber, for example, has increased over 50% since 1961.

The industry has reacted to these increased costs by introducing new construction methods to increase efficiency, substituting lower cost materials and taking advantages of economies of scale. The larger high-rise and tract builders have been able to negotiate contracts for one year's supply of "commodity" materials such as cement, reinforcing steel and brick. Despite these efforts, construction costs have been increasing faster than general inflation.

BUILDING MATERIALS PRICES HAVE GONE UP STEADILY

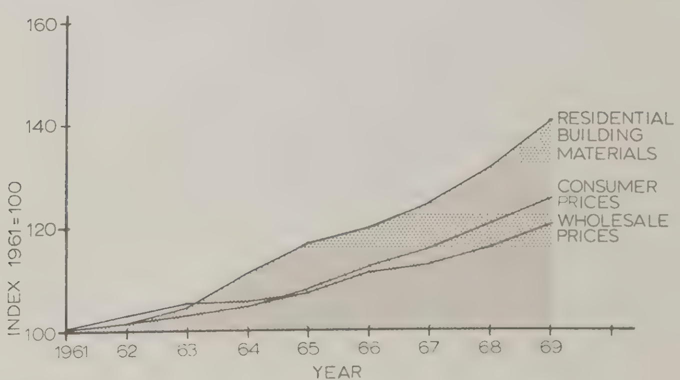


FIG.3.7

Source: Ref. 24

Administrative and Municipal Problems

Problems beset the developer at all stages as he attempts to progress from the concept and design stage of a project to the point of final approval. The process is a complex one and typically involves planning board, municipal council, county and provincial governments, and others. This approval process undoubtedly contributes to developers' risks and adds to costs. While outside the scope of this report, such problems must certainly be noted here as part of the overall reasons for high housing costs.

THE OUTLOOK IS FOR HOUSING PROBLEMS TO WORSEN

Housing activity in the past has been very sensitive to overall economic conditions. Costs have been rising steadily from year to year, regardless of production levels or unemployment. There is little reason to suppose that either of these patterns is about to change. While the backlog of demand for housing is not yet critical, it could become serious if production is not stepped up. We have estimated the current backlog at about 54,000 units; it could move up to 65,000 (almost a year's production) by the end of 1970, because of this year's fall-off in starts. There is a danger that the backlog could reach proportions which would exceed the industry's capacity to produce - even by working at full capacity over long periods.

HOUSING REQUIREMENTS TO 1980 3·2

The overall requirements for housing over the next ten years are important in assessing the opportunity for system building in Ontario. Even more important is where the houses and apartments will be needed and how many of each type will be built

REQUIREMENTS WILL BE LARGE BUT GROWTH RATE WILL SLOW

The requirements for housing will continue to increase steadily over the next 10 years. However, it is not expected to match the unprecedented growth rate that has been experienced in Ontario since 1965.

Our analysis of the Ontario market indicates that annual requirements will increase from the current level of about 82,000 units to about 102,000 units by 1975 and 115,000 units by 1980 (Figure 3.8). This represents an annual rate of increase of about 4.5% through 1975 and 4.0% through 1980, compared to an average annual increase of 7.3% experienced between 1965 and 1970.

This is our best judgment of requirements. It means a total production of more than one million new dwelling units by 1980. On a more conservative basis our analysis shows that this requirement could be reduced as much as 22%,

HOUSING REQUIREMENTS WILL INCREASE BUT
GROWTH WILL BE AT A SLOWER RATE THAN RECENT YEARS

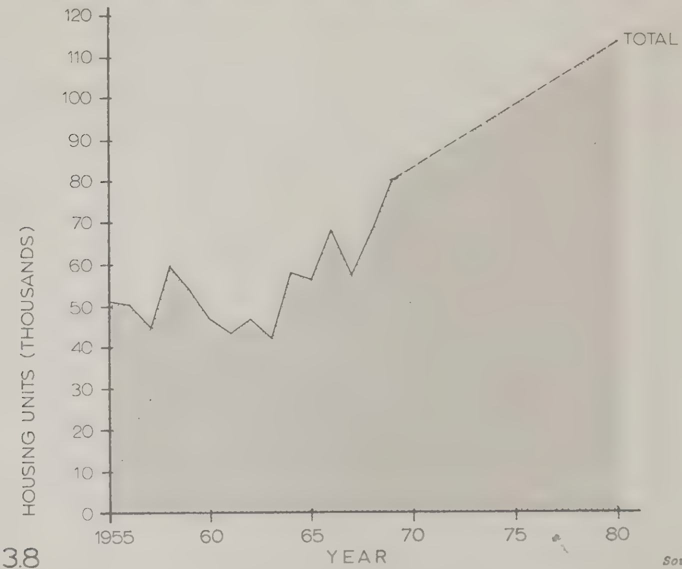


FIG.3.8

Source: Peter Barnard Assoc.

to a total of approximately 800,000 units. On the other hand demand could reach nearly 1.10 million units under more favourable conditions. (Appendix B outlines the methods used to develop these projections).

Our approach to developing projections of Ontario's future requirements has involved three important factors:

1. <u>Estimates are based on population projections for Ontario and the all-Canada forecast of housing requirements</u>: The most important indicators of housing needs are: the growth and makeup of the population, their ages, the rate at which they form families, and their preferences regarding the kinds of accommodation they need. To translate these factors into housing requirements for Ontario, we have related the most recent population projections prepared by the Ontario Department of Treasury and Economics to the components of housing

demand developed for the all-Canada forecast of housing requirements to 1961 prepared for the Economic Council of Canada.

2. Projections do not consider year-to-year fluctuations: The sensitivity of housing demand to changes in the money supply, interest rates and the overall economic climate make it very difficult to predict annual housing production with any accuracy, even over the short term. Thus, our estimates are based on the assumption that the long-term housing demand is strongly tied to the basic demand structure generated by the growth and changing age structure of the population.

3. Estimates assume continuing improvement: Over the past several years the rate of housing completions has provided for a steady improvement in the overall housing conditions, as reflected by such things as the declining number of families living together and replacement of substandard housing. Our estimates assume that this kind of improvement will generally continue at levels established over the past several years.

DEMAND WILL BE CONCENTRATED IN AND AROUND TORONTO

Based on historical trends in dwelling completions and projected population growth, only three of the ten economic regions of Ontario will experience rapid growth over the next decade. Of these, the Central Ontario region, which includes Toronto, is by far the most important and is expected to account for 61% of the total (nearly 630,000 new housing units) over the ten year period (Figure 3.9). This

FIG. 3.9

represents a marked increase over its present share of the total demand which has been about 55% over the past 5 years.

The Niagara region, which includes Hamilton and Burlington, is the second most important region. It is expected to account for 10% of the total (about 105,000 units). The other area of significance is Eastern Ontario which includes Ottawa, Kingston, Cornwall and Brockville. This region is expected to require 104,000 new housing units (about 10% of the total).

Thus, these three regions collectively will account for more than 80% of all new housing in Ontario - a fact that will be very important to system builders.

Of even greater significance is the concentration expected within a 100-mile radius of Toronto. More than 75% of all new housing in the province will be built in this area. This could mean approximately 765,000 units over the next ten years.

HIGH & MEDIUM DENSITY HOUSING WILL DOMINATE THE MARKET IN THE '70s

Over the past 10 years there has been a marked shift toward higher density living — mainly in high-rise apartments. This trend is expected to continue but with a change in emphasis from apartments to other forms of high-density housing such as row houses, low-rise or garden apartments and new forms of medium-density housing (Figure 3.10).

MAJOR GROWTH WILL BE IN MULTIPLE UNITS

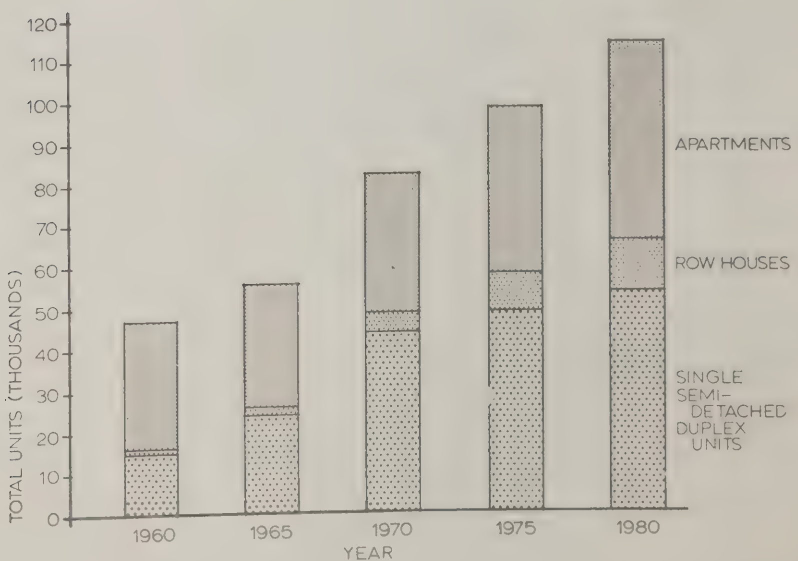


FIG.3.10

Source: Peter Barnard Assoc.

Changes in accommodation preferences and needs relate to age, marital status, and the economics of renting vs. buying. In other words, needs and preferences have to be reconciled with ability to pay—a factor that has important implications in Ontario.

Expected changes in the age structure of the population indicate a strengthening in the demand for home ownership. During 1961-66 the 25-34 age group, which typically accounts for the largest proportion of home purchases, remained relatively unchanged. But there were substantial increases in both younger and older age groups. This appears to have been one reason for the marked shift to apartment construction in the early '60s. Over the next 10 years the 20-24 year age group will grow at a lower rate, whereas the 25-34 age group will increase rapidly.

Demand for single-family units will depend to a great extent on their cost as compared to apartment rentals. As indicated in Chapter 1, the cost of home ownership is beyond the capabilities of an increasing proportion of the population - and there is no sign of a reversal of the trend to increased costs. Thus it appears that the indicated demand for single-family house ownership cannot be met and will likely be replaced by some lower-cost alternatives, such as medium density low rise accommodation or condominium row houses.

For these reasons it appears likely that single-family house building, which has remained at a relatively stable level over the past 10 years, will increase only gradually despite the increase in numbers of its potential customers. On the other hand, multiple dwellings are

expected to increase from 44,000 units during 1969 to 67,000 by 1980 equivalent to 58% of all new housing. However by 1980 nearly 15,000 units or 13% of the total multiple dwelling units is expected to be for low-rise medium-density housing, compared to 4% in 1969.

OPPORTUNITIES FOR SYSTEM BUILDING IN ONTARIO 3·3

The opportunity for system building in Ontario must be judged against the foregoing review of housing problems and the anticipated levels of production that will be needed to meet requirements in the next 10 years.

In making this assessment of the prospects for system building, we must also keep in mind its performance in solving the particular problems of other countries (which are by no means the same as those of Ontario).

SYSTEM BUILDING HAS SOLVED SPECIFIC PROBLEMS IN OTHER COUNTRIES

As discussed in Part 2, system building was introduced to deal with specific housing problems in other countries. It has been generally successful in dealing with these problems, and in the process has contributed to an overall improvement of the conventional industry and some lowering of costs.

Specific Problems

System building developed in Northern and Eastern Europe

to deal primarily with two major housing problems:

- Large backlogs of demand
- Severe shortages of skilled labour

Industrialization of the building process proved an effective answer to these problems and, despite many difficulties system building has developed to the point where it is now being used extensively in Eastern Europe and, to a lesser degree, in several Northern European countries.

Other Benefits

As a by-product to overcoming the housing shortages and lack of skilled labour, system building has produced some benefits and cost savings either directly or through increased competition and introduction of new skills.

- Some Cost Savings: Most interesting from Ontario's point of view is the impact that system building has had on costs in Europe. Despite claims of some system builders, our analysis of European experience indicates moderate savings of around 10% at most, and in high-rise housing only. In low-rise, system building has generally demonstrated little cost saving. It is important to note that these savings were usually realized in competition with relatively unsophisticated conventional building in Europe.
- Increased Competition: The development of system building and the threat it posed to the conventional builder has forced the latter to become more efficient. Thus it may be argued that the introduction of system building has contributed to some overall cost reductions by fostering improvement in the conventional industry.

- New Skills: System building has introduced to the housing industry much needed management, cost control and planning skills. The large-volume producers, faced with the greater complexity of management and co-ordination required to effectively manage system building, have been forced to bring in new skills and more professional managers. This ultimately results in a housing industry becoming more receptive to the innovation that is so vitally needed.

United States' Experience

The country of most interest to Ontario is the United States, where the conventional industry has many of the same characteristics as the Ontario housing industry.

While the United States, like Ontario, face problems of escalating housing costs, its major housing problems closely parallel those experienced in Europe after World War II. A huge backlog of demand has been demonstrated to exist and the present housing industry lacks the production capacity to overcome it. There also appears to be a growing shortage of skilled construction workers. These are the same conditions that stimulated development of system building in Europe and are the prime reasons for the U.S. Government's present encouragement of system building.

ONTARIO'S PROBLEMS ARE DIFFERENT

Our analysis of the Ontario housing industry indicates that the problems are somewhat different from those that stimulated system building in Europe and the United States.

1. Ontario's housing shortage is not as serious as shortages in Europe following World War II nor does it match the

present U.S. situation. While housing production in Ontario has not kept pace with the need and a backlog has developed, the shortage is by no means serious enough to justify a crash program of system building.

2. The Ontario housing industry has the production capacity to meet future demands. There are strong indications that the Ontario housing industry has the capacity and flexibility to respond to demands over the next 10 years. For example:

   - Past Performance: In the past, the building industry has demonstrated its ability to cope effectively with sharp year-to-year increases in demand (Figure 3.11). For example, between 1967 and 1969 the number of dwelling unit completions jumped from 58,000 units to 80,000 units, an increase of 38% over 2 years. Also, the industry has practically doubled its production since the early '60s.

SHARP YEAR TO YEAR INCREASES IN DEMAND HAVE BEEN READILY ACCOMMODATED

FIG.3.11

Source: Ref. 26

- Immigration: An unique characteristic of Ontario is the immigration of experienced construction workers. Unlike other countries, which face serious labour shortages, Ontario has a continuing supply of experienced construction workers, who come here from other countries and other parts of Canada (Figure 3.12).
- Organization: Ontario builders and subcontractors have unusual flexibility and are confident that given the opportunity, increasingly higher levels of production can be maintained without serious labour shortages. This is not to say that shortages of specific skills will not occur during peak production years but that the industry has the flexibility to adjust to increasing production levels.
- Entry of System Builders: The recent entry of system builders into Ontario has added substantially to the industry's capacity. Three new plants have recently

IMMIGRATION HAS PROVIDED A CONTINUOUS SUPPLY OF EXPERIENCED LABOUR

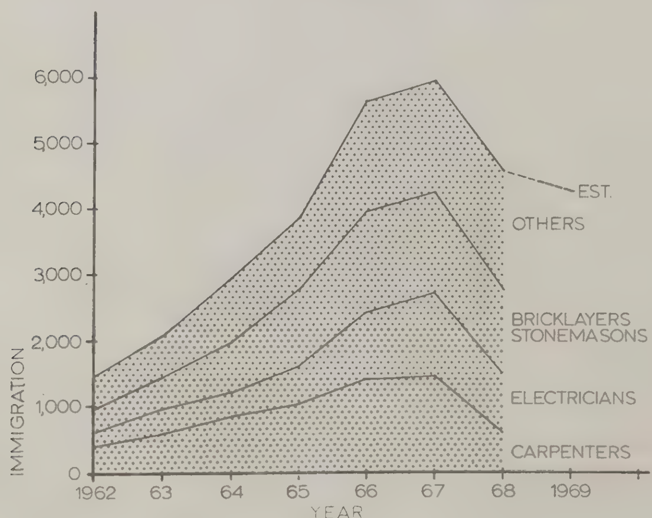


FIG.3.12

Source: Ref. 34

come on stream. A fourth and possibly others are planned for next year. Between them the three existing system builders have a production capacity of more than 5,000 units on a 2 shift basis, approximately equivalent to 6% of all 1969 housing production.

Although Ontario appears to have the production capacity needed to meet our forecasts of requirements, if pressures build up due to increasing backlogs during the early '70s, "make-up" demand could strain the industry's capacity to produce.

3. Ontario's Problem is Cost: Ontario's major problem relates not to the housing industry's ability to produce, but to the availability of funds to ensure continuing high levels of production and to producing housing at a cost that the people with the greatest need can afford. Since Ontario's over-riding problem is one of cost, then system building in Ontario must be evaluated primarily in terms of its ability to effect cost savings.

SYSTEM BUILDING CAN MAKE A CONTRIBUTION

Despite the differences between Ontario's problems and those of other countries, system building can make a contribution here. But it should not be expected to bring about major savings in the overall cost of housing. System building can help lower or at least keep down the cost of one aspect of housing costs - construction. It can do so by:

- Replacing skilled craft labour with semi-skilled factory labour;
- Reducing on-site labour and vulnerability to work stoppages;

- Providing competition for the conventional builder (although the Ontario building industry is probably one of the most advanced in the world, there are still opportunities for improvement; the advent of system building will stimulate the conventional builder to look for and adopt more innovative construction methods to compete effectively).

Another component of overall housing cost is financing. Here system building's rapid site assembly can decrease financing costs to some extent by allowing earlier occupancy.

MAJOR OPPORTUNITY IS IN HIGH-RISE APARTMENTS

Of the many factors that make up the cost of a dwelling unit, system building can directly affect only the cost of the building. Other factors, such as land cost, interest rates, supply and demand relationships, and financing costs can only be affected by government policy and changes in political organization.

System building can have little impact on the cost of materials. A wide variety of materials go into a house and no single material accounts for a major proportion of the total cost. Therefore, even if a new material were significantly cheaper it would have little impact on the total cost. Also, bulk purchasing and the related economies of scale give the system builder little advantage over the larger conventional builders who are now purchasing the major materials on the basis of long-term contracts and volume.

Thus, the major opportunity for system building is to reduce the other components of construction cost — direct labour, indirect labour and overhead. The best opportunity

for system building will be in those markets where the ratio of labour to final sale price is highest.

1. <u>High-Rise</u>: The major opportunity will be in high-rise housing. Labour and materials in high-rise account for a larger proportion of total costs than in single-family housing; thus a reduction will have a greater impact on total cost (Figure 3.13). Big volumes are concentrated on a single site, which permits easier handling of materials and less transportation. And high-rise housing is typically highly standardized and thus lends itself to industrialization and economies of bulk purchasing.

   In addition to the cost-saving opportunities, another reason why high-rise housing is the most attractive for system building is that much of future housing demand in Ontario will be this type of construction (see Chapter 2).

2. <u>Low-Density</u>: Low-density opportunities appear less attractive over the near term. The conventional industry

THE OPPORTUNITY FOR COST SAVING THROUGH SYSTEM BUILDING IS GREATER IN HIGH RISE

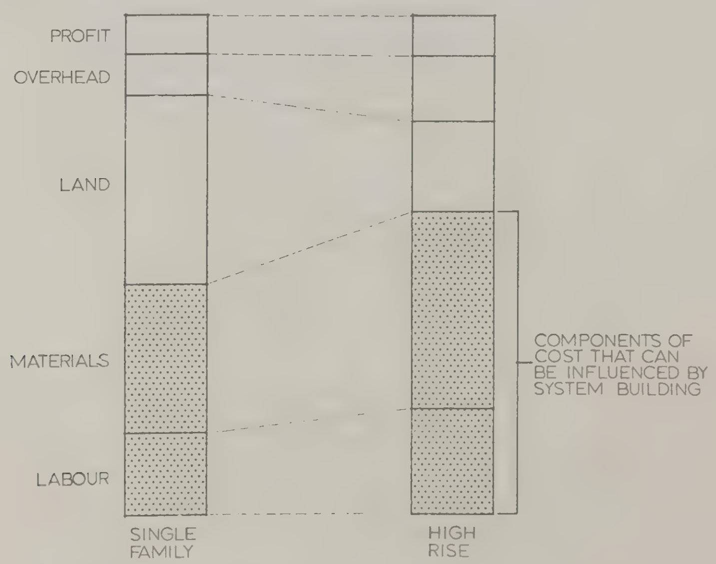


FIG.3.13

Source: Peter Barnard Assoc.

is already industrialized to some extent through the use of sub-systems and prefabricated components. Labour and material being a smaller proportion of total costs in low-density (compared with high-rise), the opportunity for savings is smaller. Moreover, the uniformity of system building tends to be more of a problem in low-density housing.

To date, most system building of single-family dwellings has been carried out using sections or boxes. These efforts do not appear to be particularly successful.

Experience in Europe also tends to confirm these observations. From our analysis, system building has made little progress in reducing construction costs on low-density housing.

COMPONENT BUILDING COULD OFFER A BETTER SOLUTION

The systems approach can also be applied to the building process through what might be called "component building". Like system building it is directed at increasing productivity through factory production and reduction of on-site activity. It represents a further stage in the evolution of the existing conventional industry but it is also compatible with system building. Whereas system building industrializes structure, component building emphasizes standardization and industrialization of other components.

Industrialization of Major Components

A common definition of a component is "a manufactured item which has at least two of its three principal dimensions fixed and is therefore difficult to modify on site".

The conventional building industry already uses a large number of minor components. They are relatively small in size and have limited complexity (bricks, windows, doors, plumbing fixtures, electrical fixtures, heating components and appliances are some examples). All of these components are highly industrialized in their manufacture, and most are available in a limited range of sizes.

Increased productivity and less on-site labour content could be achieved if larger or more complex components could also be introduced into the housing industry. Considerable advantage could be gained by industrializing the manufacture of those components which occupy major proportions of the cost of building and take significant amounts of time and skilled labour to produce by on-site methods.

These components could include a variety of types. Simplest forms would be cladding systems probably with windows, insulation and finish already in place; prefinisher partition systems, perhaps with doors already installed; prefabricated plumbing and electrical systems and a variety of other possible components more complex than those in use today, but still capable of efficient manufacture.

Sponsorship and Marketing

A major difference between a component approach and a system-building approach to the building industry is in the sponsorship and marketing aspects. The sponsor of a large-scale component would logically be a manufacturer already related to the building industry who would develop the idea, undertake or commission the product design, develop manufacturing facilities and market the product to owners, designers or builders through an existing sales organization.

The development of a complete building system requires a considerable amount of capital for the construction of a new factory and purchase of equipment; wherever major components could be manufactured by sponsors with existing manufacturing facilities. As an example, an existing steel fabrication plant could decide to produce a steel-frame bathroom core unit making use of existing cutting, welding and other shop facilities to manufacture plumbing trees and structural frame. Other types of manufacturing organization outside the building industry could also enter the component field without large capital investment.

Compatible with System Building

The development of a more component-oriented approach represents a natural evolution from the techniques currently in use by Ontario's conventional building industry. Moreover, such components could be equally adaptable to use by system builders. For example, if a manufacturer made the decision to manufacture and market a bathroom core unit this could be introduced into a conventionally built project and also become an additional component in a building system. As a result, the development of a component approach would be compatible with both system and conventional building.

Logical Evolution

As we have shown, the conventional building industry in Ontario is already approaching a more systems-oriented approach to the building process. It has developed forms of repetitive technology, adopted a considerable amount of prefabrication of components, developed more integrated forms of organization and

acquired considerable management skills.

Thus, component building represents a natural evolution from the simple forms of component prefabrication now used by the conventional building industry, to the development of more complex components. The component approach has a major advantage over the system building approach in that it removes one of the major stumbling blocks in system building the difficult marketing problem. A major component could be marketed to a variety of possible end users, whereas a building system has a somewhat limited market. Where a conventional builder might be persuaded by reasons of cost or performance to include a major component in his design, it would be a considerably different matter to persuade him to supplant his entire construction with a building system. Therefore, building systems must be marketed primarily to owners.

Needs Leadership in Standardization

In a building system all decisions regarding standardization are taken by a single sponsoring organization, starting first with the building structure. The structure sets the framework for standardization of other components, and decisions on component design, jointing and performance requirements are also made by the sponsor in the light of his assessment of market requirements.

In comparison, the sponsor of a major component faces a very complex task in deciding dimensional and functional requirements for his product. For example, a manufacturer wishing to produce a bathroom core unit has to decide on what range of floor-to-floor heights are to be produced, what options, if any, should be available in interior finishes, fixture design and locations, etc.

If important decisions such as those related to basic dimensioning are left up to individual component manufacturers, then the benefit of competition between manufacturers of similar products will be largely lost, since all components will be produced in different dimensions and to different standards. In addition, lack of adequate guidelines on standardization may discourage many potential component manufacturers from entering the market because of uncertainties regarding the amount of variety in sizes and jointing which would be acceptable to purchasers of the components. As with system building, too much variety in design lowers potential cost savings.

Component building could only be a viable proposition under circumstances which would encourage numerous companies to make the necessary investment in product development and marketing. A necessary pre-requisite is the adoption of industry-wide dimensional and functional standards around which component design can be based. This type of standardization is not likely to evolve naturally in the fragmented and highly competitive conventional industry. The initiative must be taken by major industry associations or government agencies with building programs significant enough to have an effect on the entire industry.

REQUIREMENTS FOR SUCCESS 3·4

The successful development of system building in Ontario will depend on the system builder's ability to meet three major requirements:

- Maintaining continuity of demand;
- Developing effective management and organization;
- Selecting the optimum building system

Research and development and industry standardization largely outside the control of individual companies, will also be important.

MAINTAINING CONTINUITY OF DEMAND IS KEY TO SUCCESS

The system builder must ensure continuous operation of his plant if he is to operate efficiently. The nature of the Ontario housing market offers limited opportunity for aggregating demand and this will present a difficult problem for system building.

Continuous Operation is Essential

Maintaining sufficient volume and continous demand enable a constant level of production. Intermittent demand creates factory scheduling problems lowers efficiency and raises costs. The most difficult problem facing the system builder serving an open market is to maintain a relatively constant level of production so that his plant can operate

within acceptable tolerances every day. This means not only achieving the required volume, but also being able to schedule production to avoid month-to-month changes. A manufacturing plant does not have the flexibility of the conventional building process. Adding or eliminating a shift, for example, involves a great deal of planning, training or reshuffling of personnel. Intermittent demand seriously lowers efficiency and limits the system builder's ability to compete with conventional builders.

Problems of Low Volume

Low volume prevents economies of scale because bulk purchasing and repetitive production can only be achieved with relatively high volumes. Since large conventional builders already enjoy the benefits of bulk purchasing, system builders must concentrate on labour efficiency. This means high volume contracts that permit a high degree of standardization and repetitive production.

Another Problem is that Different Designs are Impossible

The only way to remain competitive at low volumes is for the system builder to have a highly-standardized product. However, in an open market, variety of design is likely to be an important requirement.

Opportunities in Ontario are Limited

Opportunities for maintaining high volume and constant levels of demand in Ontario are few. Unlike the European countries where governments control huge building programs, the bulk of housing in Ontario is produced by relatively small private builders.

There are, however, a handful of large-scale housing programs by larger developers and, of course, OHC. These large programs would appear to be ideally suited to system building. Also, there are some private land holdings by individuals and companies which are big enough for large-scale developments suitable for system building.

On the other hand, there is no province-wide long-range urban development program with detailed housing targets which would ensure continuing demand. Perhaps even more seriously, the housing industry's vulnerability to the vagaries of the money market, coupled with the tendency of governments to tinker with controls, make scheduling of production very difficult.

Small Initial Market

Given the current conditions and even with reasonable market penetration, it would appear that Ontario can support relatively few system builders. Only the greater Toronto area, referred to in Chapter 2, has the prospect of sufficient volume and concentration of demand to support a system building industry. By 1975, of the 78,000 dwelling units per year which will be needed within 100 miles of Toronto, 49%, or 38,500 are expected to be in high-rise buildings which offer the best opportunity for system building.

Even in those countries providing support and incentives for system building, penetration of the market has been slow. In Britain, for instance, it took 8 years for system builders to reach 30% of the market, even with substantial government support. Ontario is not in a position to provide that kind of support, nor are there the same compelling reasons for it to do so. We feel that a 15% penetration of high-rise and 10% of low-rise housing by 1975 is fairly optimistic.

This would mean 5,800 system-built high-rise units per year. The 3 system builders who already have plants in Ontario have the collective capacity to produce about 13,000 units per year on a one-shift basis, and 5,000 on a two-shift basis respectively (Figure 3.14). In addition, another 2 or 3 firms appear to be sufficiently committed to the idea of system building to be on the verge of entering the market.

The high ratio of land to total dwelling cost means that overall costs are less sensitive to labour savings. This is one reason why it has been difficult for the system builder in Europe and the U.S. to compete in this market. For the low-rise market (row, semi-detached, duplex and single family housing) the forecast 10% penetration would mean some 4,000 units per year in the primary marked area within 100 miles of Toronto.

Few Systems

The implication of all this is that Ontario can

ONTARIO CAN SUPPORT RELATIVELY FEW SYSTEMS

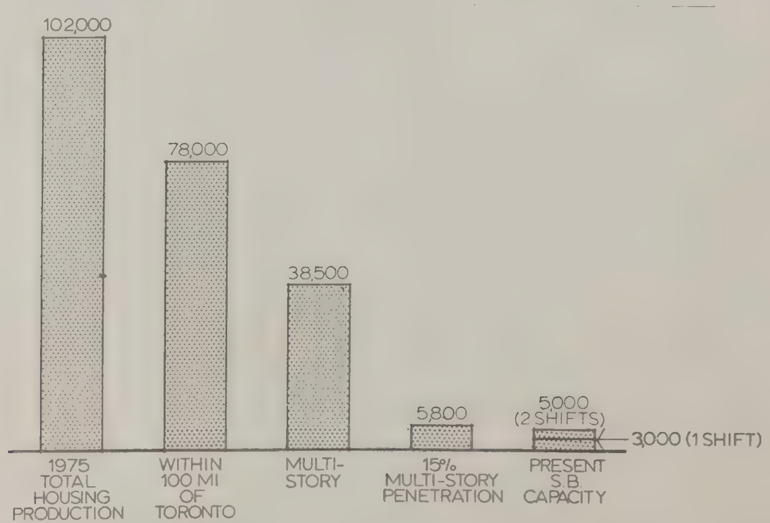


FIG.3.14

Source: Peter Barnard Assoc.

support relatively few system builders and may already have, in the existing systems and those with announced intentions as many as it can support. In a free economy there is always an opportunity for a competitor to enter the market, of course, and further entrants could displace markets from existing systems or aim at different market segments.

However, it is worth pointing out the experience of system builders in the United Kingdom. Out of the more than 300 systems developed there, most of which are technologically viable, only 6 are being used to any extent. The reason for this may be that systems were developed around technological solutions rather than realistic marketing needs.

EFFECTIVE MANAGEMENT AND ORGANIZATION ARE ESSENTIAL

System building, if it is to achieve any cost advantages, will be highly dependent on the sponsor's capability for organizing and managing the total building process. Some conventional builders, particularly for high-rise construction, have over the past few years evolved their own "systems"which take advantage of some of the same savings available to the complete system builder. A key requirement for success in the Ontario market will be the management and organization of the total building process to take full advantage of industrialization.

Organizational Forms

1) Owner-sponsored; 2) developer builder-sponsored. The common characteristic of the two is their familiarity with the building industry. The unique advantage of the owner/sponsor is a guaranteed market and continuity of

demand. Developer/builders do not have the same control over demand, but they are typically experienced in marketing and have a real understanding of the risks and problems of residential construction. In addition, they have experience in organizing on-site operations. This "know-how" could be even more important in Ontario since the system builder will be competing with conventional building (which was not the case in Europe where specific markets were reserved for system building) and an understanding of conventional costs and methods could prove invaluable.

Few Owner or Developer Systems Possible

Few opportunities exist in Ontario for either owner or developer/builder-sponsored systems. Despite some trends to concentration there are still relatively few builders with sufficient resources to develop and market a building system (in 1969, only 13 companies in the province produced more than 100 units). The opportunity is further limited by the fact that some of the larger developers, who between them control some 25% of the Metro Toronto market, have already formed a cosortium to own and operate a system building company.

OHC is virtually the only other potential sponsor with a large building program but even it does not control a building program as large as it European counterparts.

Trend to Outside Sponsorship

Large industrial or investment corporations seeking diversification opportunities are sometimes attracted by the growth potential of housing, and the building industry's apparent need for industrialization. They feel that they have the large financial resources and management skills needed to capitalize on system building.

Apart from the consortium of developers mentioned above, two or three "outside" sponsors have entered the market in Canada - or are contemplating doing so. There has also been some interest from building materials manufacturers who see a system building operation as a potential large captive market for their products.

IN SELECTING THE OPTIMUM SYSTEM THERE IS NO UNIVERSAL SOLUTION

There is no one system that provides the best solution to all of the problems of all types of buildings. The problems of high-rise building, for example, are quite different from those of single-family houses. Design flexibility is not nearly so important for high-rise as for row- or single-family housing, where uniformity is often unacceptable to the user. Similarly, if a system builder is serving markets involving relatively low-volume contracts, he might have difficulty meeting the high volume requirements of a capital-intensive plant.

Focus on Markets - not Technology

The key to selecting or developing viable systems is to start not with technology but with the market — first by defining the markets to be served, then by carefully identifying and establishing the needs of these markets in terms of design flexibility, volumes, speed of construction, importance of cost savings, compatability with existing industry, etc. Having set criteria that a system must meet to be competitive, the next step is to evaluable systems against those criteria and select the ones that best meet the criteria.

This is particularly important in Ontario where there is no such thing as a captive market. (In Europe,

particularly in the socialist countries, governments have provided system builders with large markets with fairly well defined characteristics not exposed to competition. The North American consumer is very market-oriented, so the builder/developer has to be extremely sensitive to user needs and must market his product effectively. The point is worth stressing that Canadian system builders, unlike their European counterpart, can expect little government support, which will place great importance on the quality of their marketing effort.

STANDARDIZATION AND RESEARCH AND DEVELOPMENT CAN CREATE A FAVOURABLE CLIMATE

Research and development, and industry standardization, were critical to the introduction of system building in Europe; they will be very important in Ontario, too.

Research and Development

Research and development are required for any new departures in technology to become commercially viable. Ontario can take advantage of the extensive technological research and development done in Europe, but little of the back-up research into the environment applies here. The Ontario market is different; users' needs and tastes are different; the political climate is different; and the conventional building industry is more advanced. Thus, there is an important need for local research and development if system building is to get off to a good start here.

Standardization

Standardization is fundamental to industrialized building whether it be system buillding or component building. Greater

standardization of design and of regulations affecting all types of building would specifically assist system building to get started. The building system standardizes certain aspects of design and construction to achieve economies of scale. If some limitations on variety of design could be applied throughout the industry it would not only aid system builders but might also help conventional builders to cut costs through greater use of industrially-produced major components.

Such rationalization might include standards for housing (which need not create uniformity of appearance or layout) dimensional coordination, component standardization and even standard building plans. Also important to the system builder would be province-wide adoption of a uniform building code, zoning laws and subdivision regulations. Without such uniformity the system builder is unable to achieve the full benefits of system building because he is forced to overdesign for most areas in order to meet the most stringent municipal requirements he will encounter. The ways that building codes and zoning regulations could inhibit system building will be discussed in more detail in the next chapter.

While there appears to be no single obstacle big enough to completely block system building in Ontario, its ability to compete effectively could be influenced by a number of potential constraints. These include:

- Labour
- Building codes
- Land assembly
- Zoning
- Transportation
- Vested interests

ORGANIZED LABOUR COULD SEE A THREAT TO JOB SECURITY

Organized labour may be a principal constraint to the development of system building in Ontario. Ontario does not appear to have the same critical shortages of construction labour that face other places where system building has developed. Therefore, substantial industrialization of the building process may be seen as a threat to the job security of skilled workers employed in conventional building.

The nature of the construction industry makes new developments highly dependent upon the cooperation of the labour unions. These unions are organized along craft

rather than industrial lines (i.e., they bargain on behalf of a whole trade, rather than with individual employers). This tends to make them resist technological changes and innovations, particularly those that alter or eliminate the nature of traditional craft skills.

New Skill Classifications

An objective of system building is to replace high-cost skilled on-site labour with semi-and low-skilled factory labour. System building also creates the need for new skills both to manufacture the components, and also to assemble and erect components on-site. The multi-trade skills involved with these new jobs do not fit the present trade classifications, therefore new lower specialized skill classifications will be needed — logically with lower wage rates. The existing craft unions are unlikely to totally accept these new classifications, possible giving rise to jurisdictional disputes.

Employer/Union Relations

System builders already in business have worked out arrangements whereby plant unions are recognized by the local craft unions since they all belong to the AFL-CIO. However, this is no guarantee that there will be continued cooperation. More likely there will be instances where system builders will be forced to make concessions that will prevent them from realizing the full savings potential.

In their dealings with employers over the past few years, unions have held the balance of power due to their control over hiring and the fact that their approach to bargaining is more unified than that of the contractors'

organizations. Efforts are being made to counteract this imbalance with the introduction of labour legislation aimed at providing more equitable negotiations in the construction industry. How this will work out and be accepted by both parties is not certain at this time. However, it is an indication that labour may not be able to exercise as much power as it has in the past.

Over the long run, unions will no doubt accept industrialized building methods, but along the way they will likely resist them, particularly if systems gain a significant share of the market and in the process reduce the need for skilled labour.

BUILDING CODES ADD UNNECESSARY COSTS

Building codes in their present form stand in the way of the development of system building. This is not so much because they limit its application, but because they can prevent full realization of the cost-saving potential. There are 3 main problems: 1) the lack of uniformity of building codes across the province; 2) the wide range of interpretations that are put on the codes by local building inspectors; and 3) the "specification" nature of the codes which leave little flexibility for the use of new materials.

Lack of Uniformity

To meet the different codes of each municipality, the system builder must either limit his standardization and produce different models for different localities, or he can over-design to meet the most stringent code requirements. Either way involves higher costs. Another cost

penalty comes from the excessive testing and delays involved in getting approvals for the use of new materials and designs.

Varied Interpretations

Perhaps more important than the lack of uniformity between different codes is the wide range of interpretations of the individual codes by the municipal officials whose job it is to enforce them. This could mean a system builder having to make further modifications to meet the requirements of individual building inspectors.

Over-stringent Specifications

Building codes have typically specified the characteristics of permissible materials and construction methods without making provision for dealing with new materials. This "specification" approach to codes may effectively prohibit the use of innovative materials or techniques that are a feature of some of the more advanced types of systems, or least involve a system builder in a lengthy (and hence costly) procedure for getting approval, since local officials typically do not have the experience or resources to evaluate new approaches and materials.

Impending Progress

Recently, important progress has been made in dealing with the code problem. A report is before the provincial government which, as its principal recommendation, advocates province-wide adoption of the National Building Code.[13] If this report is implemented, it should do all that is needed to clear up the code situation. It seems that while over the short run building codes will present problems and in some cases inhibit system building, the steps already taken should prove adequate to deal with the situation.

LARGE-SCALE DEVELOPMENTS MEAN LARGE TRACTS OF LAND

Maintaining the satisfactory volume levels and continuous production needed to achieve the benefits of system building requires large projects, which in turn require serviced land tracts of sufficient size to accommodate them.

The pressure of increasing population in urban areas has used up much of the land that is suitable for residential development. Such land as there is tends to be in the hands of established conventional developers or speculators from whom it is only available at high prices. Land assembly is further complicated by the fragmentation of land ownership and speculation brought about by availability of trunk services. As a result, sites available at a reasonable cost are far away from centres of employment and therefore involve greater risks for the builder.

Some land banking is taking place and several large developments are under way which could take advantage of system building. In general, however, availability of land could pose a major problem for system building development.

ZONING RESTRICTIONS LIMIT HIGH-DENSITY DEVELOPMENT

Municipalities surrounding major urban centres sometimes use zoning regulations to restrict the high-density housing development that is most suitable for system building.

Local municipalities are currently responsible for providing sewers and water, police and fire protection and other services for their residents. The large increases in population brought about by high-density development involve a greatly stepped-up volume of such services. To avoid placing a large tax penalty on existing residents who control the voting, municipalities often set zoning regulations that restrict high-density development by specifying, for example, minimum lot sizes, building heights and land coverage.

Over the short term, zoning is not likely to be a major obstacle to system building since most projects which use it are likely to be either in the cities or in large developments outside of major urban centres. However, zoning laws could present problems if and when system builders have to depend on developments in outlying municipalities.

HIGHWAY REGULATIONS LIMIT USE OF SOME TYPES OF SYSTEM

Present Department of Highways regulations will have little effect on the transportation of the panel systems which have been successful to date. These regulations do, however, pose problems for the sectional-home and box-system manufacturers. The strict enforcement of the twelve-foot width limitation without special approval seriously limits design flexibility. While special approval for the transportation of extra wide loads can be obtained, the escort requirements make it unfeasible for regular use.

There are indications that the Department of Highways may be considering making the regulations more stringent.

tations, and the organizational and management processes involved.

Contractors

The contractor's job will change, too. Since a large proportion of the construction work is carried out in the plant, the job of the building contractor changes from that of an overall coordinator of men and materials to that of erecting and assembling prefabricated components. With system building, scheduling and control of activities is much more important than for conventional construction. Building contractors will have to develop these skills or they will be replaced by people perhaps not as well versed in conventional methods but trained in project management.

Manufacturers' Contribution

System building implies standardization and close co-ordination of all components. This means the manufacturer must become involved in the early design phases if the system builder is to benefit from price breaks due to volume and from design recommendations of the manufacturer to reduce costs or improve co-ordination with other components. If steps can be taken towards industry standardization of dimensions and performance requirements, then manufacturers can make an important contribution towards a component approach to building which can benefit both system and conventional building (see Chapter 3).

Any changes reducing the acceptable load dimensions or weight could have serious implications for system builders, particularly builders of three-dimensional systems.

VESTED INTERESTS COULD MOUNT OPPOSITION

In addition to labour there are other groups in the construction industry who could see their positions challenged by the advent of system building. While these groups may not go so far as to present obstacles to system building development, absence of support from them could be a handicap. Their active support, on the other hand, could make an important contribution. The three principal groups concerned this way are architects, building contractors and manufacturers.

Architects' Role

Architects have an important role to play in the acceptance of system building. Combining the production advantages of standardization with design flexibility needed to assure user acceptance will require the kind of imagination and ingenuity that the architect can provide. However, to do so will involve a change in orientation: the integration of organization so important in system building will mean a change in the traditional position of the architect as an impartial consultant to the owner and leader of the construction team. This is already taking place in the conventional residential industry, and the advent of system building is likely to speed this change. This will require that the architect be thoroughly familiar with system building, including an understanding of the materials, production and erection techniques, design limi-

SUMMARY AND CONCLUSIONS 3·6

Since the mid-sixties, demand for housing in Ontario has outpaced supply, with the result that a backlog of demand has been accumulating. The underlying cause of the accumulating shortage is not an inability on the part of the industry to produce housing, but rising costs that have put house ownership and rental well beyong the means of an increasing proportion of low- and middle-income families

It appears that the two primary reasons for system building development in other countries - critical shortages of both housing and labour - are not present in Ontario.

However, Ontario does have problems of its own and system building can make a valuable contribution by holding down costs and by stimulating the Ontario building industry to continue to improve its efficiency.

Another "systems" approach — component building — could offer some solutions to Ontario's problems, but it would need influential leadership.

To gain a significant share of the market, system builders will have to demonstrate their capability for holding down construction costs. The major opportunity for realizing cost savings is in high rise buildings where labour constitutes a greater proportion of the total cost. However, there is only one market area of significance in Ontario and this market will support only a few system builders. Also, development of this industry will not be easy. A number of constraints will have to be overcome and system builders will have to market their products effectively.

Despite these obstacles, system building will flourish if it can clearly demonstrate its ability to hold down construction costs.

4

O.H.C.'S ROLE IN SYSTEM BUILDING

We have concluded that, while system building can by no means resolve all of Ontario's housing problems, it does offer the potential for helping to control rising construction costs, and on this basis it should be given the opportunity to compete effectively with conventional building.

OHC, with one of the largest building programs in North America, is in a position to exercise significant influence over this development, but the role OHC adopts must be consistent not only with the potential of system building itself, but also with OHC's own overall objectives.

In Chapter 1 we shall describe why OHC is so influential by reviewing its size, growth and future programs. In Chapter 2, by considering OHC's existing relationships and responsibilities and by discussing the broad choice of involvement in system building that OHC faces, we develop a series of major criteria for selecting the role OHC should actually play.

Finally, in Chapter 3, we set out the recommendations on the specific programs OHC should implement.

THE IMPORTANCE OF OHC 4·1

Because of the size and nature of its housing programs, its status as a government agency, and its access to public funds, OHC is in an unique position to influence the development of system building in the Province.

OHC CAN ASSURE DEMAND AND PROVIDE ESSENTIAL SUPPORT

The key requirement for success in system building is to maintain sufficient demand to keep plants operating continuously at economic production levels. The industry also needs a range of back-up services which OHC is better able to provide than any other organization in Ontario.

Size and Growth

Since its inception in 1964, Ontario Housing Corporation has grown rapidly, and now ranks with the largest industrial corporations in the province. Originally conceived to meet the need for low-income family and senior citizen housing, the scope of the Corporation has broadened to include student housing, land banking, lot leasing and mortgage financing to assist medium-income families. This broadened range of responsibilities has required new and different programs and the staff to operate them. OHC's current annual volume in public

and student housing alone is equivalent to some 10,000 units, which makes the Corporation by far the largest housing developer in the province.

This growth in activity has been reflected by the increase in assets and staff. In 1969 the total assets of OHC were over $300 million, while its staff now totals more than 800 (divided equally between salaried office staff and hourly-paid maintenance employees). It has become the largest housing developer on the continent, and with 27,000 units under management, it is the third largest landlord in North America (after the public housing authorities of New York and Chicago).

Three Housing Programs

OHC has three major housing development programs, each of which lends itself to the application of system building. The largest is the family rent-geared-to-income program which involved completions of almost 5,000 units in 1969. The second largest is the senior citizen housing program, under which 1,300 units were completed in 1969. The third is the program of Ontario Student Housing Corporation, which comes under the operational control of OHC, and which accounted for 3,000 beds in 1969.

These three types of housing are well suited to the application of system building because of the scale of production and the homogeneity of the different categories of users which permits a high degree of standardization.

Sources of Funds

As noted in the previous Chapter, private housing activity in Ontario is highly sensitive to the state of the money market, which makes it difficult for private developers

to make long-term plans, since it is almost impossible to guarantee the availability of mortgage funds at an economic rate.

Since OHC's funds are supplied by the Federal and Provincial governments it is not faced with the uncertainties of the money market to the same extent as private developers.

Because of its size and because of its special position in the money markets, it seems clear that OHC will continue (and probably enlarge) its role as the major developer of housing in Ontario. Thus the corporation can have a significant influence on the success of system building.

Future Outlook

The complexity and nature of Ontario's housing problems as we outlined them earlier suggest strongly that effective solutions will require government involvement. This indicates a continuing and increasingly important role for OHC. As already noted, housing is beyond the means of a large and growing proportion of the population, which automatically increases the demands on OHC's major services at a similar rate. At the same time, demand for senior citizen and student housing is increasing. The demands for OHC's services are expanding steadily and its programs will grow according to the availability of Federal and Provincial funds. Among OHC's problems will be to evaluate needs and set up priorities for the allocation of those funds.

In considering the problems of setting priorities and allocating limited resources, it is useful to review OHC's past production and the extent to which that production is satisfying needs in the various programs.

Family Rent Geared to Income

Our studies have shown that practically all families below medium income are paying too large a proportion of their income for shelter and thus require assistance. However, OHC's primary concern is families below the "financial assistance" level (for an explanation see Appendix B, Section 4).

As at June 1970, OHC had under management approximately 27,000 units for people in this category and were satisfying approximately 12% of the need in this area. The Table 4.1 shows what will be involved in achieving progressively higher levels of penetration (an objective of satisfying, say 50% of all Ontario families below the financial assistance level would require an annual rate of production of 8900 units through 1980).

FAMILY RENT-GEARED-TO-INCOME

ADDITIONAL UNITS REQUIRED TO REACH VARIOUS MARKET SHARES BY 1980

(THOUSANDS)

ALTERNATIVE PENETRATION BY 1980	TOTAL NUMBER OF UNITS REQUIRED	TOTAL ADDITIONAL UNITS REQUIRED BY 1980	AVERAGE ANNUAL PRODUCTION TO REACH REQUIRED MARKET SHARE BY 1980
25%	58	31	3.1
50%	116	89	8.9
75%	173	146	14.6
100%	232	205	20.5

TABLE 4.1

Senior Citizen Housing

The requirement for senior citizen housing is based on the number of families and non-family households with heads between the ages of 65 and 80 who are below the financial assistance level (for a fuller explanation see Appendix B, Section 4). To date, OHC has completed 3,000 senior citizen housing units outside the metropolitan Toronto area and expects to complete another 3,000 units this year. These units, together with the dwellings controlled by the Metro Toronto Housing Corporation and other agencies represent approximately 8% of the present need for senior citizen housing in Ontario. Production levels for meeting progressively higher objectives (penetration objectives) are shown in Table 4.2. Thus, a penetration objective of say, 50% by 1980, would require an annual production rate of 3,100 per year.

SENIOR CITIZEN - RENT GEARED TO INCOME

ADDITIONAL UNITS REQUIRED TO REACH VARIOUS MARKET PENETRATION BY 1980

(THOUSANDS)

ALT. PENETRATIONS BY 1980	TOTAL UNITS REQ'D.	TOTAL ADD. UNITS REQ'D. BY 1980	AVER. ANNUAL PRODUCTION TO REACH REQ'D. MKT. SHARE BY 1980		
			TOTAL	METRO	EX-METRO
25%	36	24	2.4	1.2	1.2
50%	73	61	6.1	3.0	3.1
75%	109	97	9.7	4.8	4.9
100%	146	134	13.4	6.7	6.7

TABLE 4.2

Student Housing

Since it started in 1966, Ontario Student Housing Corporation has produced a total of 5,900 beds for students. The annual level is expected to increase to 2,500 beds in 1970. By the beginning of the 1970/71 school year it is expected that approximately 25% of the university students will be housed in student residences provided from all sources. To maintain this level, OHC could be called upon to produce about 3,900 beds per year through 1980. The estimate of probable requirements is based on a survey of five universities. Universities sampled expected to have to provide beds for an average of 60% of the additional students they will be accommodating over the next few years (individual universities within the five sampled expected to have to provide beds for from 30% to 100% of additional enrolment). To meet a 60% objective 9,300 beds per year will be required to 1980.

PRODUCTION RATE OF ONTARIO UNIVERSITY BEDS REQUIRED TO ACCOMMODATE VARIOUS PERCENTAGES OF INCREMENTAL STUDENT POPULATION

(THOUSANDS)

PENETRATION OBJECTIVES FOR INCREMENTAL STUDENT POP.	REQUIRED	TOTAL ADDITIONAL BEDS REQUIRED	AVERAGE ANNUAL PRODUCTION NEEDED TO MEET OBJECTIVES	% OF TOTAL STUDENT POPULATION ACCOMMODATED
25%	69.5	38.6	3.9	25.0
50%	108.3	77.6	7.8	39.5
75%	147.1	116.4	11.6	53.0
100%	185.9	155.2	15.5	67.0
60% (PROBABLE)	123.7	93.0	9.3	45.0

TABLE 4.3

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These analyses provide some measure of the magnitude of OHC's role in Ontario. In the next chapter we discuss and define that role in specific terms.

OHC'S ROLE IN SYSTEM BUILDING 4·2

It is self evident that any role played by OHC in the development of system building in Ontario must have as its objective an improvement in the Corporation's ability to service the housing needs of the Province. That role must recognize OHC's existing responsibilities and relationships and the kind of contribution system building can make in Ontario based on judgements of its performance in other countries. In this Chapter we will review these considerations, develop criteria for assessing the Corporation's role and finally define the role that we believe should be adopted by OHC.

OHC'S ROLE MUST RECOGNIZE THE CONTRIBUTION THAT SYSTEM BUILDING CAN MAKE

Without reviewing in detail our major conclusions about system building (See Part 3), it will be helpful to recall that system building cannot be expected to provide the panacea for all Ontario's housing problems. On the contrary, it can have little or no effect on two major problems: the high cost and availability of both funds and land.

The major justification for supporting system building in Ontario is that it can probably help control the upward pressures on construction costs. Providing system builders can be assured of consistent levels of demand, the efficiencies of

industrialization should reduce costs, while the additional competition provided by system building should result in more efficient conventional building. But the case for system building on this score is not yet clearly established. The evidence from other countries is that system building has reduced construction costs to some extent — but the comparisons are against conventional building industries that are notably inefficient by Ontario's standards. Nevertheless, cost control is the major justification at present for any involvement in system building on the part of OHC.

A second justification for system building could arise in the fairly near future if the present backlog of demand is not reduced. The uncertainties of the current economic situation (with its affect on the availability of funds) make the situation difficult to predict with any certainty. A growing backlog of demand would create a housing situation in Ontario more like that in Europe a few years ago and create an opportunity for system building based on its capability for high-volume production.

OHC HAS RELATIONSHIPS AND RESPONSIBILITIES TO CONSIDER

As a Crown Corporation, OHC has particular responsibilities to the public at large and to various groups and organizations which will influence, and to some extent limit, the role that the Corporation can properly play in system building.

Consideration must be given to the following relationships:

1. Federal Government: As the provider of 90% of the funds for rent-geared-to-income housing, the federal government,

through CMHC, is concerned with any actions taken by OHC. Such actions should be consistent with the plans and programs of CMHC.

2. Provincial Government: OHC is directly responsible to the Minister of Trade and Development of the Ontario Government, which also provides 10% of the funds for rent-geared-to-income housing and the funds for the HOME lot program and mortgage financing. Furthermore, the Ontario Government is answerable to the public for OHC decisions and policies, so any action taken by OHC must be acceptable to the provincial government as a whole, as well as officials of other departments who may be affected.
3. Municipal Governments: The municipalities are OHC's major customers, and provide 7 1/2% of the operating funds for rent-geared-to-income housing and senior citizen housing. Thus, any changes in housing policy must take the municipalities into account.
4. The Public: Housing is one of the more sensitive political areas and one with which the public has typically been heavily concerned, so any activities in connection with system building should consider likely public reaction.
5. OHC's Own Internal Organization: Any role adopted by OHC will have to be implemented by the Corporation. New programs should ideally be capable of implementation by present staff, or at least with minimum additions.
6. Tenants: A major purpose of OHC is to meet tenant needs within the financial and political constraints under which OHC operates. Thus, any action or policies OHC adopts must take into consideration not only the effects those actions may have on the tenants, but also probable tenant reaction.

7. The Construction Industry: OHC programs now constitute such a proportion of the total residential construction activity in Ontario that any change in policy could have significant impact on the industry. As a public body OHC cannot favour one segment of the business community over another without clear justification.

OHC CAN CONSIDER A WIDE RANGE OF ROLES

Theoretically at least, OHC could select any one of a wide range of roles, varying in accordance with the degree of system building involvement it elects to adopt.

At one end of this "involvement spectrum", OHC could choose, for example, a completely passive role. On this basis OHC would provide no encouragement of any kind but would merely accept system building in proposal calls. The Corporation would apply no resources to system building and would undertake no changes in internal organization or procedure to accommodate it.

At the other end of the spectrum would be total involvement. OHC would specify system building for all OHC projects, would encourage the system builders in every possible way and would undertake major changes in internal organization and procedures to accommodate them.

On the basis of the findings presented thus far in this report these extremes of involvement can be intuitively discarded as being inappropriate. Now we must develop some guidelines or criteria to assist in the selection of the proper role for OHC.

OHC'S ROLE MUST MEET SEVERAL MAJOR CRITERIA

Based on an assessment of Ontario's housing problems, on the known performance and anticipated potential of system building, and on a recognition of the special responsibilities of OHC, we have established several criteria to provide guidance for the development of OHC's role in system building. These criteria fall into three main categories:

Defining OHC's Involvement

- Since the major justification for system building in Ontario is to control construction costs, OHC's activities should basically be oriented towards this particular benefit of industrialization.
- Because there is still some question about the viability of system building in Ontario, OHC's financial commitment to it should be controlled — preferably by setting a strict budgetary limit.
- Based on known data there is no justification for OHC undertaking major changes in its organization to facilitate the development of system building.
- There is no justification for OHC to provide direct subsidy to system builders "to get them off the ground", because enough of them are already in production.

External Factors

- OHC's activities should not depend on changes in Federal, Provincial or Municipal policies, nor on action by these bodies, since there is no guarantee that such changes or actions could take place.

- OHC should avoid having system building become identified with low-income housing because the system-built product should not be looked upon as cheap housing and it is most undesirable to attach identifiable characteristics to persons of low income.

The Building Industry

- OHC's contracting terms and procedures should provide an equal opportunity for system and conventional builders to ensure fair competition without working to the advantage or disadvantage of either.
- OHC's contracts for system building should not be confined to a single builder, despite the fact that the opportunity for the industry in Ontario currently appears limited. Because of OHC's potential influence in the industry it would be unfair to consistently select a single system builder; such a step could also tend to increase the possibility of design monotony in OHC projects.

OHC'S ROLE SHOULD PROVIDE THE ARENA FOR COMPETITION

Consideration of the possible alternatives and the foregoing criteria leads us to this recommendation for OHC's role:

> OHC SHOULD CONDITION THE ENVIRONMENT FOR THE DEVELOPMENT OF SYSTEM BUILDING SO THAT SYSTEM BUILDERS CAN EFFECTIVELY COMPETE. TO DO THIS, OHC SHOULD PROVIDE THE ARENA FOR FAIR COMPETITION BETWEEN SYSTEM AND CONVENTIONAL BUILDING.

This will involve OHC undertaking actions that will:

1. Help the emerging industry to overcome start-up problems; and
2. Change OHC's own building program approaches to allow system builders to compete, without in any way working to the disadvantage of conventional building.

A lesser role than this would seriously reduce the industry's chances of survival and thus fail to introduce the much needed ancillary benefits that system building can bring to the Ontario housing industry. Also it would not give system building the opportunity to demonstrate its cost-saving potential when operating under favourable conditions.

To do more than assist in system building development would be equally undesirable. There is still some question whether system building can compete effectively with conventional building even over the long term. Thus, to subsidize its development to the disadvantage of conventional building might serve to raise the cost of OHC housing with little promise of future benefits.

RECOMMENDATIONS 4·3

In providing the arena for fair competition between system building and conventional, OHC should take actions which assist system builders to achieve maximum operating efficiency and foster improvements in the building industry - but which in no way work to the disadvantage of conventional builders. OHC should undertake the following 5 specific programs that meet these criteria and also provide direct benefits relating to the Corporation's overall programs and obectives:

1. Modify contract procedures to provide continuity of demand;
2. Initiate a program of dimensional standardization for OHC dwellings;
3. Develop and encourage long-range planning;
4. Sponsor an annual competition for innovative housing;
5. Undertake a program of applied research and development.

1 MODIFY CONTRACT PROCEDURES TO ENSURE CONTINUITY OF DEMAND

OHC should modify its current contract procedures to permit the larger and longer term contracts needed by system builders to achieve the full benefits of industralization.

In addition to helping the system builder maintain

economic levels of production and thus compete more effectively with the conventional builder, this program also offers the conventional builder the opportunity to make bulk purchases and achieve some economies of scale. Therefore, by letting larger and longer term contracts OHC's building program can benefit from these economies.

Implementing this recommendation will involve no major capital investment, nor will it require increased operating expenses. Rather, it will require changes to existing procedures and policies to accommodate two programs: multi-site contracts and serial contracts.

Multi-Site Contracts

To aggregate demand and allow larger and longer term contracts, OHC should group requirements for several projects within a given geographic area into a single proposal call. All proposals would be on OHC-owned land and, as far as possible, should require buildings of essentially similar characteristics. Proposals would become one package evaluated on the usual value-for-money basis. Because of the extra effort required to prepare designs and costs for more than one site, we recommend that these proposal calls be modified to a 2-stage type of competition, the first in which preliminary proposals are evaluated and narrowed to the best 3 or 4, followed by a second stage in which these 3 or 4 are required to submit more detailed proposals, from which the successful proponent is selected.

Because of the co-ordination required to select the group of projects, this type of proposal call probably could not be implemented until early in 1971.

Serial Contracts

As another way of providing continuity of demand, OHC should initiate a program of serial contracts. Under this approach certain proposal calls would carry an incentive whereby the successful proponent would be given the opportunity to obtain contracts for buildings of equivalent size and design characteristics in each of two succeeding years based on the initial price.

All projects would be on OHC-held land and contracts in years 2 and 3 would be within a reasonable radius of the contract awarded in year 1. OHC would sign a contract with the successful proponent for the first project together with letters of intent for contracts in years 2 and 3 with the proviso that sufficient funds and adequate sites were available and provided the proponent's performance on the initial contract was satisfactory.

Serial contracts would provide the builder with year-to-year continuity of work based on a cost established by the first year's contract. If a builder can achieve reasonable assurance of longer-term production requirements, he can typically offer a more competitive price. This technique should encourage keen competition within the industry and should be particularly helpful to system builders who need continuity to achieve optimum efficiency.

We would recommend that this program start with a proposal call to be issued in the Fall of 1970. It should be for a modest-sized project in the order of 300 to 500 units per year.

2 INITIATE A PROGRAM OF DIMENSIONAL STANDARDIZATION FOR OHC DWELLINGS

OHC should undertake a major program of dimensional standardization to foster greater industrialization of the building process by system, conventional and component builders.

OHC, by virtue of the size and characteristics of its programs is uniquely positioned to lead the way to the standardization of dimensions, plans and sub-systems that is so important in achieving higher levels of industrialization.

Achieving greater standardization will be of considerable benefit to system and conventional building, although the greatest benefit may accrue to component manufacturing, an evolutionary trend that we have noted in Ontario and a development that, if encouraged, may in the long run provide the best solution to the problem of holding down construction costs.

This program will involve OHC establishing in-house capability for analyzing needs and developing standard solutions, a process that requires skill and experience in all aspects of housing technology. This program should progress in 3 stages: 1) examine existing buildings; 2) develop dimensional and minor component standards; 3) develop major component standards and type plans.

Examine Existing OHC Buildings

OHC should carry out an examination of a representative sample of its buildings constructed over the past 2 or 3 years to determine the extent to which common dimensional and

functional characteristics exist between buildings. This study should be confined initially to multi-storey buildings and should include, if possible, buildings of major private developers in the province.

Develop Standards for Principal Dimensions and Minor Components

OHC should next develop standards for principal dimensions such as floor to ceiling and sill heights, balcony and staircase dimensions, etc. These would be incorporated into all proposal-call documents. Standards for windows, doors, partitioning and other minor components should also be developed.

Develop Standards for Major Components and Type Plans

The standardization program should then progress to establishing bathroom and kitchen type plans and other types of major components which would benefit most from industrialized production. The program should then progress to the development of standard plans for senior citizen, family and student units.

The standardization program should be coordinated with Federal government agencies such as CMHC and the Department of Industry, Trade and Commerce who are also interested in these matters. In order to achieve maximum benefit from this program, OHC should strongly support current efforts to achieve uniform building standards for the entire province.

3 DEVELOP AND ENCOURAGE LONG-RANGE PLANNING

OHC should assume a leadership role in developing forecasts of housing need, in formulating long-range housing plans for the province and in encouraging municipalities to develop projections of their own housing requirements.

The existence of long-range housing forecasts and plans would assist the housing industry in adopting a much more planned approach to the building process. As we have emphasized, system builders in particular, must be able to plan for future production. Furthermore, these forecasts and plans would assist OHC's land purchasing activities upon which the multi-site and serial contracting procedures recommended earlier would depend.

As one of the largest developers and managers of housing in North America and as the major Provincial government agency with responsibility for housing, OHC is ideally positioned to meet the need for housing forecasts and plans for the province. In implementing this recommendation, liaison with other Federal or Provincial agencies concerned with housing would be, of course, essential.

Implementing this program will involve strengthening and re-organizing OHC's Planning and Research Department to add planning skills and expertise in forecasting future housing needs - a highly specialized activity. This Department should have three major assignments: 1) conduct a continual study of housing needs; 2) develop long-range plans; 3) promote planning by municipalities.

Continual Study of Housing Needs in the Province

Starting with the forecasts contained in this report, this department should carry out any refinements felt

necessary in order to develop more detailed short- and long-term projections for the province and its major geographic regions.

Developing Long-Range Plans for OHC

Based on the overall study of housing need, this Department should prepare forecasts for OHC's major programs as a basis for determining long-range plans for the Corporation.

Promote More Planning by Municipalities

Since the plans and programs of municipalities have a major impact on OHC's own programs, any long-range planning by the Corporation would have to be co-ordinated with the needs of municipalities which to date have had neither the skills nor the motivation to prepare their own plans. OHC is well positioned to encourage them to do so.

4 SPONSOR AN ANNUAL COMPETITION FOR INNOVATIVE HOUSING

OHC should initiate an annual competition to stimulate the development of new and creative solutions to housing problems.

One of the major obstacles to the implementation of new housing ideas is the lack of an opportunity to test them in use. The private housing industry, with its limited resources, is unwilling either to pay the premium typically involved or to accept the risks. Thus OHC can perform a valuable service to system builders and conventional builders by providing the opportunity to test new ideas.

This program would involve setting aside a small

project of 75-150 units each year and holding a competition for innovative ideas in housing design and construction. The winning ideas would then be incorporated into the project. Thus, unlike most competitions where the winning designs are seldom built, the innovator could be assured that his ideas would be applied.

This competition could be carried out in one of two ways: developer proposal or 2-stage competition.

Developer Proposal

The competition would seek entries on a normal design/build basis, much like any OHC proposal call. This would provide close integration between the design and build activities and would ensure that the innovative proposal could be carried through to a successful conclusion.

Two-stage Competition

An alternative is a 2-stage approach. The first stage would be the one in which design ideas were the basis for the competition. Three or four winners would get prizes. OHC would then couple these winning design entries with builders, request prices for the project and award the contract to the best design/build entry.

We also recommend that the selection of winning entries be made by a jury or panel made up of OHC staff, directors and outside industry representatives. The composition of the jury should change from year to year. Some years the competition could be of an international nature and the jury selected accordingly.

5 UNDERTAKE A PROGRAM OF APPLIED RESEARCH AND DEVELOPMENT

OHC should undertake a sustained program of research and development to provide much needed support for the application of new methods, improved designs and innovative products in the Ontario housing industry.

There are limited facilities in Ontario for accumulating and disseminating research findings and developments in building technology or for sponsoring investigations that would specifically benefit the Ontario industry. OHC's position as a government agency and largest builder and manager of housing in the province makes it the logical candidate for performing this important function.

OHC should establish an Applied Research Department consisting of a small group of building experts who, in addition to assuming primary responsibility for the standardization program and annual competition recommended above, would undertake the following 4 activities: 1) monitor system building projects; 2) study special problems; 3) study projects in use; 4) sponsor outside research.

Monitor System Building Projects

Since OHC is likely to be involved in several system-built projects, this staff should develop and implement methods of monitoring projects at all stages, with the purpose of evaluating designs and construction techniques.

Examine Special Problem Areas

From time to time particular technical problems occur with OHC projects. The Applied Research Department could undertake studies to recommend remedial measures and methods of avoiding the occurrence of the problem in the future.

Conduct In-Use Studies of Projects

The group could also monitor use and maintenance problems in a variety of projects. The annual pilot projects will be particularly useful for evaluating new and innovative solutions to design and building problems.

Sponsor Outside Research Activities

Once the group had developed sufficient expertise and knowledge of the Corporation's activities, serious consideration should be given to expanding its budget to allow it to initiate and implement applied research studies by outside groups with particular areas of expertise.

*   *   *   *   *

The implementation of the above recommendations will result in many direct benefits to OHC as well as to system builders and the conventional building industry. To guide OHC management, we have prepared a supplement to this report which discusses the recommendations and their implementation in greater detail.

5
APPENDICES

APPENDIX A : FURTHER IMPLICATIONS OF SYSTEM BUILDING

In doing the research for this report, our study of system building has been considerably more detailed than the outline contained in Part 1. This Appendix has been prepared to assist OHC staff members and others to understand in greater detail some of the considerations involved in working with system building. These involve the design (both of the system itself and of the buildings on which it will be used), production, transportation and construction. The implications vary considerably according to whether a frame, panel or box system is involved, and these differences will be pointed out.

RESTRICTIONS ARE PLACED ON DESIGN

The building designer must adapt the limited variety of components provided by a system to suit the needs of a specific project and site.

While most systems can theoretically be modified to meet special design requirements, to call for such customizing is generally both inefficient and costly. The restrictions placed on building design by a system are, in effect, a new set of "rules" within which the building designer must operate. The nature of these restrictions varies with the choice of system, whether frame, panel or box.

Site Adaptability

With most systems, foundations and below-grade work are constructed conventionally, to provide a base for the system-built superstructure. The alternative of varying the length and sizes of the standard components to suit particular site conditions normally proves too costly.

In adapting to a specific site the designer can take advantage of the structural pattern inherent in panel and box systems to span between individual footings or piles. Particularly with box systems, this can lead to considerable visual excitement (Figure A.1).

Interior Planning Flexibility

The degree of flexibility in layout of a unit varies with the type of system (Figure A.2).

In a frame system, non-bearing partitions can usually be located to suit any room requirements, with column

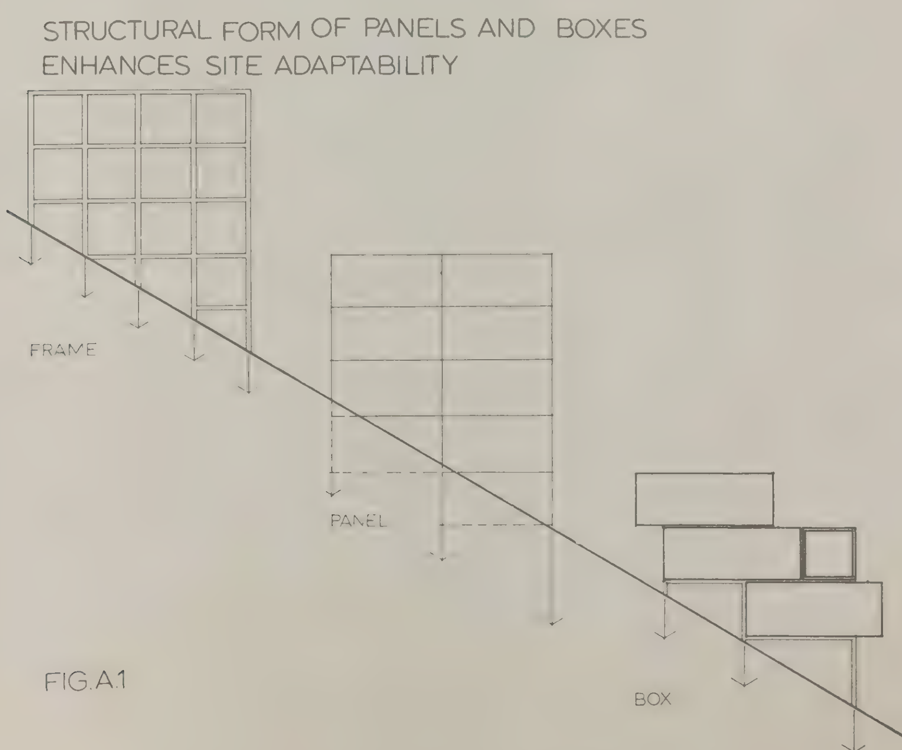


FIG.A.1

BOX SYSTEMS HAVE LESS PLANNING FLEXIBILITY THAN FRAME SYSTEMS

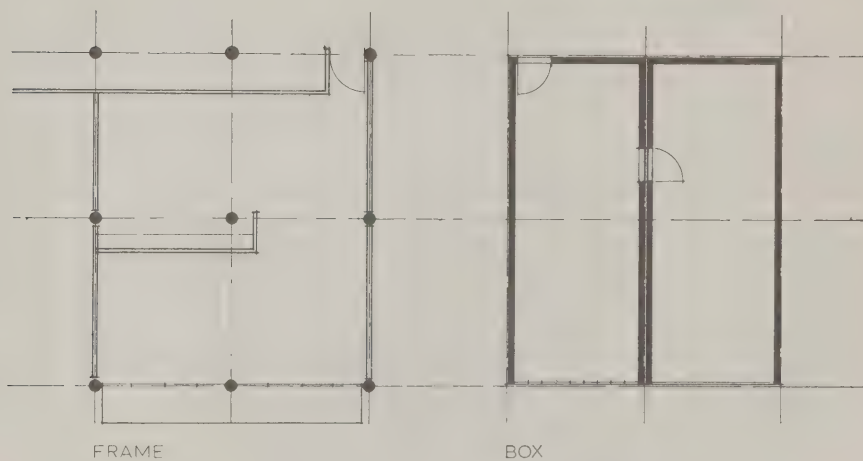


FIG.A 2

locations governed by available sizes of floor beams or planks. Panel systems usually require a more rigid adherence to specific spans between either load-bearing internal crosswalls or load-bearing facades. Box systems provide the least flexibility in unit planning, particularly if produced in an off-site factory and trucked to the site, when the width restrictions for highway transport impose limitations on the maximum room width. With some box systems, two boxes, each with one open side, may be combined to provide double-width rooms, but this procedure usually requires additional strengthening of the box at increased cost.

In panel and particularly box systems, the size and limited variety of available components often makes it difficult to avoid some wastage of space if the design must solve specific and exacting user requirements. For example, the width and length limitations on a box can determine unit areas which may be either smaller or larger than actually required. A clustered arrangement of these units to accommodate specific space requirements may also result in pockets of unusable waste space.

As a result, the economics of system building can often depend on how specific the clients' or designers' requirements are and how these requirements relate to the standard sizes produced by the system builder. If they are not closely related, the system builder may have no alternative but to provide more space than is required, or to modify his standard designs for one particular job. In either case, the result will be higher cost. This is one area where the standardization program by OHC, which is recommended in Part 4 of the main report, would be of considerable help to the system builder.

The frame system has greater flexibility of unit layout and lends itself also to multiple use requirements within the standard framework. This makes the frame system useful where such facilities as residential, retail, and recreational facilities must be combined within one single complex.

Lining up with Adjacent Buildings

When a building employing a system is being erected adjacent to an existing structure, the designer may face problems in relating window sizes, floor heights and other distinctive facade elements to those of the neighbouring

buildings for a more ordered street facade. Costly variation in component sizes may be required or the co-ordination sacrificed if the building system characteristics do not match up. Prohibitive cost restraints could make alterations of this sort in a box system virtually impossible.

<u>Unique Aspects of Box System</u>

In terms of building form, the box system has several unique advantages over other systems. These advantages stem from the fact that the box is structurally independent and requires no external structural assistance for its own strength. For example, the unit layout may be a conventional straight line pattern, or a variety of more imaginative staggered arrangements. This allows considerable flexibility in planning public and private spaces. In addition, the box units are extremely versatile in their methods of vertical installation. They may be stacked on top of each other, cantilevered, hung by cables, or plugged into a structural frame to provide a variety of visually exciting forms not normally available if conventional construction techniques were employed (Figure A.3).

The monolithic character of the box, which is on the one hand its greatest advantage is, at the same time, one of its greatest disadvantages. Since the box is installed independently of adjacent boxes, there is a double party wall between each unit, each wall being designed to withstand normal loading requirements of each unit, in addition to withstanding transportation and erection loadings. This duplication of characteristics between vertical and horizontal surfaces creates a redundant situation and a subsequent cost inefficiency.

The environmental requirements of the external shell with respect to weather resistance, acoustical privacy, and tempera-

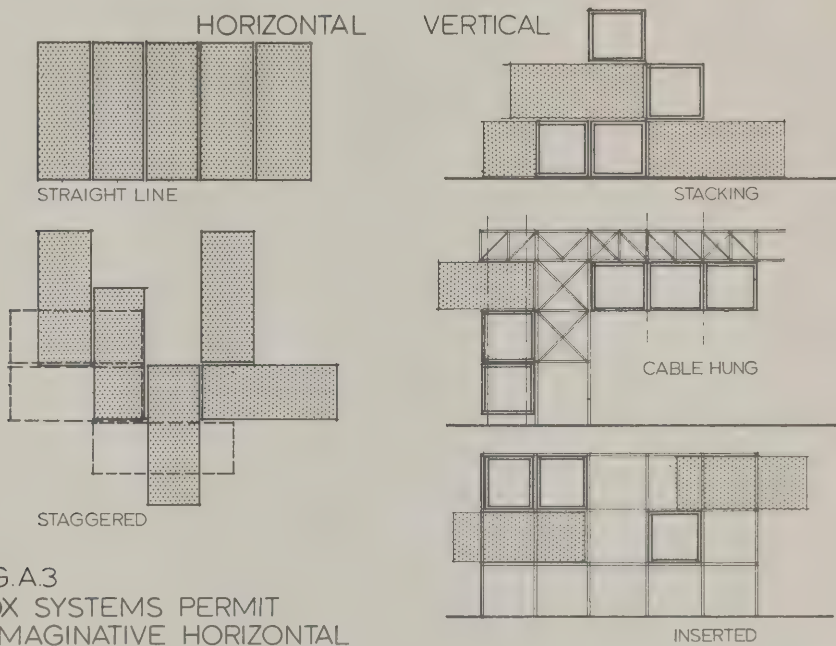


FIG.A.3
BOX SYSTEMS PERMIT
IMMAGINATIVE HORIZONTAL
AND VERTICAL PLANNING

ture control will vary at different points on the shell. Obviously, weather resistance at the external shell and the corridor wall are not the same thing, nor are acoustical requirements between a living room and bedroom unit of one dwelling and two adjacent bedroom units of different dwellings. Most production methods for box systems, particularly those using concrete, require uniform wall construction throughout. Consequently, the shell may be designed to satisfy the maximum requirement which may occur — which means some overdesign for other locations. Or it may be designed for the minimum situation in such a way that considerable on-site modification or finishing may be necessary to satisfy special cases. Either way means added cost.

User Needs

The actual needs of the users of a system-built project are no different than those of a project employing conventional construction methods. The internal spaces must provide the usual technical qualities of light, air, acoustics and safety, and the design characteristics of space adequacy, space arrangement, esthetics and maintenance for each specific activity. The external shell must satisfy the technical needs of climatic protection and acoustical and visual privacy and the design characteristics of fenestration, esthetics and maintenance.

Understanding the user needs is essential. In conventional building, failure of the designer to correctly interpret the true needs of the building occupants results in a single building that does not function properly. However, when a building system is being designed, failure to anticipate user needs correctly could be disastrous since the manufacturing facilities will be set up for the production of many components employing the same concepts of standardization.

PRODUCTION PROCESSES AND DECISIONS ARE AFFECTED

The standardization inherent in a building system permits the repetitive manufacture of major components by industrialized processes. As pointed out earlier, this is the major departure of a system building from conventional techniques. Hence, the manufacturing operation becomes of primary importance.

<u>Location of Factory</u>

Many manufacturing processes are possible, the choice for a potential building system being influenced by numerous interrelated market, design, financial and other considerations.

- <u>Off-site Factories</u> are normally used in areas where potential markets are sufficiently concentrated and transportation facilities appropriate to enable production to be concentrated at one central location. As a rule, off-site factories are capital intensive, replacing labour content with automated processes. However, there are instances of labour intensive central plants in areas where labour is inexpensive or in cases where management wishes to keep capital investment as low as possible. Often plants are converted into more capital intensive operations as volume and profits permit. Naturally, the capital required for a plant varies depending on the complexity of equipment used, land costs, quality and size of enclosing structure, etc. Total investment, exclusive of land, can vary from $750,000 to $2 1/2 million depending on the type of system and production process used.

  Note that by general industrial standards, these are not large capital outlays for a plant. Companies already supplying minor components such as bathroom fixtures or gypsum wall board require factories with considerably greater capital investments and the investment in a cement plant can exceed $20 million.

- <u>On-site Factories</u> are used where markets are too spread out for economical production, where transportation facilities are poor or where projects are sufficiently large to justify individual factory set-up. On-site

factories are often movable and successful building systems using this approach normally have several factories producing at any one time. The need to have relatively portable equipment usually results in lower capital investment than central factories and, as a result, the on-site factory approach gives a system builder considerable flexibility in varying his production facilities to meet changing market conditions.

While placing of the factory on the site removes the capital requirements for land, the system builder with an on-site factory requires an area of the site to be set aside for the factory. On cramped urban sites this may not always be readily accomplished. However, if a system is to be used in the construction of a new town or other large development, then an on-site factory is most appropriate and, in fact, can take on the capital-intensive and mechanized characteristics of a permanent central plant.

Volume and Continuity

Continuous high volume production is essential for economical operation. With the capital investment in plant and equipment, a system builder must maintain a smooth scheduling of projects through his plant. Production can be increased by adding a second shift but cannot be allowed to continue at below-minimum levels for long periods of time. Economic volume varies, therefore, depending on the capital investment in plant and equipment, production cycles, materials purchasing arrangements, labour costs and so on. Minimum economic annual

volumes could range between:

1,000 to 1,500 units (concrete panel, off-site factory)
300 to 600 units (concrete panel, on-site factory)
300 to 500 units (concrete box)
100 to 300 units (wood panel).

As we mentioned in Part 1, the multi-storey system builder's major problem is scheduling. Orders for individual projects are large and take up a considerable proportion of a year's production. Other types of manufacturing operations suffer from similar problems, but most have a major advantage over the system builder — they can manufacture for inventory when not producing for a particular job. While some have tried, few system builders are able to produce components for inventory, since small changes in component design are usually required from project to project.

In the production of a building system, large inventory is usually a sign of on-site scheduling causing a back-up of components that cannot be delivered. Where large components are involved, such as a box system, inventory space can be critical, not to mention the capital invested in such an inventory. In the case of smaller components, it is also difficult for the system builder to manufacture for inventory as the design of each succeeding building may still involve different component sizes.

Economy of Scale

Economies of scale are seldom directly proportionate to production volumes. Even when a manufacturer produces a component with limited or no variety required — such as a

standard bathroom core, for example — cost cannot decrease indefinitely as volume increases. Economies of scale vary considerably with the type of component being produced, the manufacturing facilities used, capital requirements, etc. Figure A. 4 illustrates a set of relationships. Note that costs are naturally very high with low volumes, presumably much higher than if the component were conventionally produced on-site, and that the addition of new equipment required to expand capacity causes discontinuation in the relationship. The nature of the cost-volume curve will differ for all components of a building system, so that the aggregate of cost-volume relationship for all components of a system is very complex.

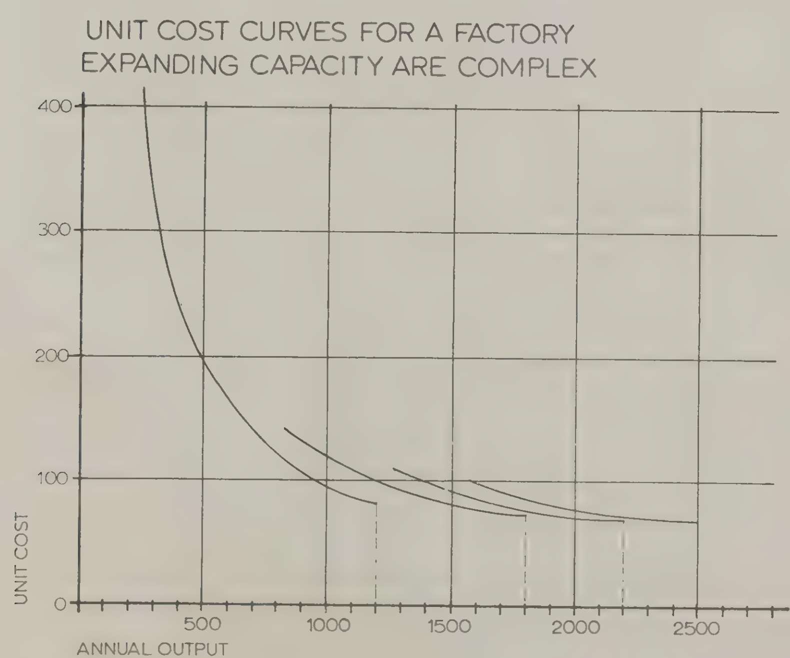


FIG.A.4

Variety of Components

In developing a system, one of the key decisions concerns the amount of variety to be permitted in component design. In the interest of achieving maximum economies of scale, minimum variety is the logical objective. However, in the interests of flexibility in design of buildings more variety is warranted in the size, shape, colour, or texture of components.

A building system must compromise between these alternatives to achieve sufficient variety in components to be acceptable architecturally, yet still be produced as economically as possible. Variety must be allowed for in the design of the production equipment, but the means will depend on the type of system. For example, the mold design for wall components might be of the vertical battery type in which the height of the finished component cannot be varied but, by changing the positions of the plates located at the ends of the component, its length could be varied in increments predetermined by fixing positions built into the mold. Variety of span in floor components could be achieved by altering reinforcing steel and varying thickness of the slab within the peripheral dimensions of a horizontal mold, also variable in predetermined increments. Variations in colour and texture would be less critical since they would be confined to the finishing activities.

Regardless of the extent of the variety in component manufacture, however, there must be a practical balance between architectural flexibility and economic feasibility. This is one of the major judgments which the system builder must make. Design flexibility will affect the acceptance

of the product, but to provide too much will increase the cost.

Finishing Quality

Since major components are manufactured under factory conditions, system building normally can achieve a higher quality of interior and exterior finish than conventional in-place construction where finishes are applied in less controlled conditions. The replacement of manual labour by automated processes also eliminates the element of human error and inconsistency in the production process.

Overall quality of finish depends, however, on the quality of jointing between components as well as the surface finish on the component itself. This is particularly true of panel systems where poor on-site jointing can cause an overall decrease in finishing quality compared to conventional construction.

Integral factory produced finishes are a characteristic feature of building systems, particulary in box systems where all finishing may be completed in the factory. Interior finishes are protected by the volumetric box component during transportation and erection, and there are no major jointing requirements during erection. The quality of finishes should be superior to finishes achieved in conventional construction.

TRANSPORTATION BECOMES IMPORTANT

Unlike conventional building which requires transportation for bulk materials and some small components, system building generally involves transportation of large prefabricated components often requiring special equipment.

Distribution Range

Transportation costs affect the range of markets that can be served. The costs of transporting large heavy loads that characterize system building, limit the area that can be effectively served by a particular manufacturer. Depending on the type of system, an economic cycle to follow may involve two deliveries per day that would include the following sequence of events. At the beginning of the day, a flat bed trailer that has been loaded with components the previous evening, is hauled to the site. The trailer is left at the site and the tractor returns to the plant with an empty trailer unloaded the previous day. The empty trailer is left at the plant, and a second loaded trailer is hauled to the site. The tractor then returns to the plant with the trailer which he delivered in the morning, and which has subsequently been unloaded at the site during his second delivery. By following such a cycle, the vehicle, loading equipment and personnel are kept busy continuously, thus providing maximum productivity. Inefficient cycling of the transportation sequence will result in idle equipment, or manpower, that will create additional costs and decrease the system builder's competitiveness.

Some system builders may claim a greater market radius than would be indicated for an efficient transportation cycle, based on their estimates that their cost advantage over conventional building can absorb increased transportation costs. Other manufacturers of lightweight frame and panel systems capable of efficient packaging may also be competitive in a wider market area since more units can be placed on a single trailer.

Economic Load

A further factor to be considered in transportation is the value of the load being delivered. Obviously, the greater the dollar value of the load, the greater the efficiency of the carrying and handling equipment. Since the value of the load may be directly proportionate to the state of completeness of the components which make up the load, it may be seen that the higher degree of prefabrication of the elements being transported, the greater the efficiency of the equipment being used. For example, a panel system with all services installed and all finishes applied is a much more valuable load than a frame system being transported the same distance. Naturally, the equipment transporting the panel system may be more costly, and because of the size of panel components, there may be few components being transported. However, the frame system components must be followed by delivery of all services, equipment and finishing materials to complete the system, thus reducing the efficiency of the initial load of frame components by the additional operations.

Highway Regulations

Highway regulations create design limitations and inconvenience for the system builder. Maximum allowable width, height and weight of loads being transported on public transportation routes, are strictly controlled by Department of Highway regulations. The most important of these is the width restriction which, in Ontario as in most areas of North America, is set at 12 ft. (although some areas in Central and Western U.S. permit 14 ft.). This poses a limitation on the design of box systems with off-site factories, and in many cases, has left no alternative but to shift the production operations to a portable on-site plant.

When it is necessary to transport large, over-sized components on public transportation right-of-ways, there is an added inconvenience and expense of special escort facilities and permits. In built-up metropolitan areas, transportation of such loads may also be limited to certain hours of the day when there is likely to be the least interference with normal vehicular movement. This is a further difficulty to be considered in the transportation scheduling cycle.

CONSTRUCTION BECOMES AN ASSEMBLY OF PARTS

Large scale, prefabricated components mean less on-site activity but require new construction techniques and equipment from those used in conventional building.

Erection Procedure

Construction of a system is concerned with the erection of components and their jointing. The greater the proportion of the building that is prefabricated, the fewer the components, and the less jointing required. Frame systems at one extreme are characterized by many components and considerable jointing. with a large portion of construction operations performed by conventional methods. At the other extreme, box systems usually involve components that are completely prefinished and construction becomes simply an operation of assembly only, with little on-site activity.

Equipment

The nature and capacity of equipment varies according to the type of system. The frame system can generally be erected using conventional equipment of relatively low capacity and

simple operation because of the smaller components. Some frame systems may even use manual labour for erection activities, which may account for the interest in frame systems in under-developed countries.

The heavy components of large panel and box systems, on the other hand, require sophisticated, high-capacity equipment that must be capable of maneuvering large and heavy panels or concrete boxes to virtually any position on the construction site. For example, the following are typical ranges in component weights:

Steel Frame	1/4 to 1 ton,
Concrete Frame	1/2 to 2 tons,
Concrete Panel	2 1/2 to 10 tons,
Concrete Box	12 to 90 tons,
Wood Box	2 1/2 to 10 tons.

The bulky nature of box systems often requires different types of site transport equipment, usually of an underslung design.

Jointing

Jointing techniques become critical. In developing the design of a system much emphasis is given to jointing design essential for efficient on-site assembly. Speed of construction, structural safety and performance all depend on jointing technology to a much greater extent than in conventional building. Performance criteria for jointing in a building system may include climatic protection, acoustical privacy, structural strength, and resistance to temperature change. Jointing technology is of major importance in panel systems since joints are subjected to structural, climatic and other requirements. Frame systems require special attention to structural characteristics of the joints only whereas in box systems jointing is less significant.

Speed

Construction speeds can be greatly increased. The assembly of large components is a quicker method of construction than on-site fabrication because the number of operations are decreased and erection is not so dependent on weather conditions, curing times, materials supply and labour. As a result, system building can achieve considerable reductions in on-site construction times compared to conventional building. Naturally, speed of erection is inversely proportional to the number of components, so that box systems can usually attain faster construction speeds than panel or frame systems.

Total construction time from initiation of contract to final occupancy is largely dependent on the system builder's ability to effectively schedule his production in plant. If this can be accomplished, then the efficiency of factory production should add considerably to overall time savings.

APPENDIX B: ONTARIO HOUSING REQUIREMENTS TO 1980

The purpose of this Appendix is to present in more detail the forecast of housing requirements discussed in Parts 3 and 4 and to describe the approach and methods used to arrive at these estimates.

It is organized under the following headings:

1. Demand vs. Need: To provide a common understanding, we define what is meant by housing demand and need, concepts about which there has been much confusion.

2. Purpose, Scope and General Assumptions: We discuss the purpose for which these forecasts have been developed, their scope and limitations, and the general approach that was taken.

3. Ontario Housing Requirements to 1980: We present our forecasts of requirements to 1980, for the Province, by areas and by types of dwellings, together with a more detailed explanation of the methodology and assumptions.

4. OHC Market Estimates to 1980: To place the OHC market in perspective, we outline the results, methodology and assumptions for the forecast of family, senior citizen and student housing segments.

1. DEMAND VERSUS NEED

In the past, there appears to have been a great deal of confusion between the terms need and demand for housing, although there are important distinctions between the two concepts. A forecast of housing needs involves value judgements about desirable levels of housing conditions and how long it should take to achieve these levels. On the other hand, an estimate of demand for housing is concerned with the actual future output and the various factors influencing the market such as interest rates, income levels, etc. As explained in a 1968 CMHC background paper:[36]

> "In a society in which all housing accommodation was allocated by public decision, the formulation of an estimate of needs would be fairly straight-forward. It might involve no more than establishing an appropriate amount of housing space for each family unit and for each adult not living in a family. In a society such as ours, however, estimates of housing needs would have to take into account not only the standard of housing conditions deemed appropriate, and the size and character of the population, but also the effects of the market mechanism on the way in which the housing would be distributed.
>
> "Various proposals have been made for estimates of needs that would take these difficulties into account. One proposal would base an estimate of housing needs on the volume of housing production that would be needed to ensure the replacement of all sub-standard housing within a given time period. Another and more useful suggestion is a concept of minimum housing needs based on that volume of housing production necessary to ensure no increase in the number of families sharing housing accommodation. Such a concept of minimum housing needs would imply a volume of housing

> production below that to which we have been accustomed although it would still imply very substantial improvements in housing conditions resulting from qualitative changes.
>
> " Neither of these concepts is entirely satisfactory although certainly some kind of indicator is necessary to the rational discussion of housing issues as matters of public policy.
>
> " In contrast to concepts of housing needs is the concept of housing demand. Only by accident would the actual output of housing coincide with a particular notion of housing needs. The effective demand for housing is determined by the size and structure of the population, which enter also into calculations of housing needs, but it is determined also by the course of incomes, land and construction costs, and by the terms of mortgage borrowing, none of which enter into the judgment of need."

Our analysis of overall housing requirements over the next decade represents a practical compromise between the two concepts of housing need and demand. In terms of need, we have assumed that all family and non-family household formations will be provided with a dwelling and that certain vacancy, undoubling and replacement rates are desirable. In addition to considering demographic trends, we have also allowed for a continuation of past tendencies in the relationship between costs, incomes, interest rates, etc., which are some of the important factors in forecasting demand. Thus, our forecast of requirements is a combination of both value judgments about needs, together with a consideration of the variables of the actual market. Details of the data used and the assumptions made in the various forecasts are contained in the respective sections of this Appendix.

2. PURPOSE AND GENERAL APPROACH

In carrying out this market analysis we had certain objectives which affected both the scope of the study and the nature of the assumptions used.

PURPOSE RELATES TO SYSTEM BUILDING AND OHC

We undertook this market analysis with the following specific objectives:

- To provide estimates of the number, location and type of housing units in order to determine the extent of the opportunity for system building in the Province.
- To obtain some indication of the numbers of units OHC might be required to build given a variety of possible management objectives, so that we could assess the likely future importance of OHC as a system building client.

In this light, the study is not meant to be precise nor could it possibly encompass all factors necessary for a detailed analysis. Our procedures were employed for very specific purposes and it is important to note that various assumptions were assessed and made in light of their impact on our overall study conclusions and recommendations.

APPROACH IS A COMPROMISE

Depending on the use of the results, there are many methods available to forecast long-term housing requirements ranging from a very detailed quantitative approach to a much broader qualitative conceptualized technique. In view of the scope and purpose of the study, it appeared

appropriate to compromise between the two extremes. Thus, where useful, we utilized the results of more detailed reports prepared by others, together with our framework and analysis of historical trends and future developments. In addition, to further assist OHC management in understanding the range of possible results and the sensitivity of the estimates to various assumptions, both pessimistic and optimistic forecasts were prepared.

ESTIMATES BASED ON 3 CONSIDERATIONS

The various forecasts of requirements for the overall province and OHC market segments are based on the following three considerations:

1. The projections rely heavily on the latest long-term estimate of all-Canada housing requirements to 1981. These have been prepared for the Economic Council of Canada by Central Mortgage and Housing Corporation [28]. They include attainment of the various goals established by the ECC and are based on the more recent population projections prepared by the Dominion Bureau of Statistics. Thus, reasonably favourable underlying economic conditions provide the general background for these projections.
2. The estimates do not consider short-term fluctuations in economic activities. They are based on the assumption that, in the long run, the demand for housing is strongly tied to the basic demand structure generated by population growth and changes within it.
3. The forecasts involve an improvement over past conditions. All new family and non-family households are provided with a dwelling and improvements are assumed in undoubling, vacancy rates and net replacements.

3. ONTARIO HOUSING REQUIREMENTS TO 1980

In this section we present our results and detailed methodology on the overall housing requirements, by geographic region and dwelling type.

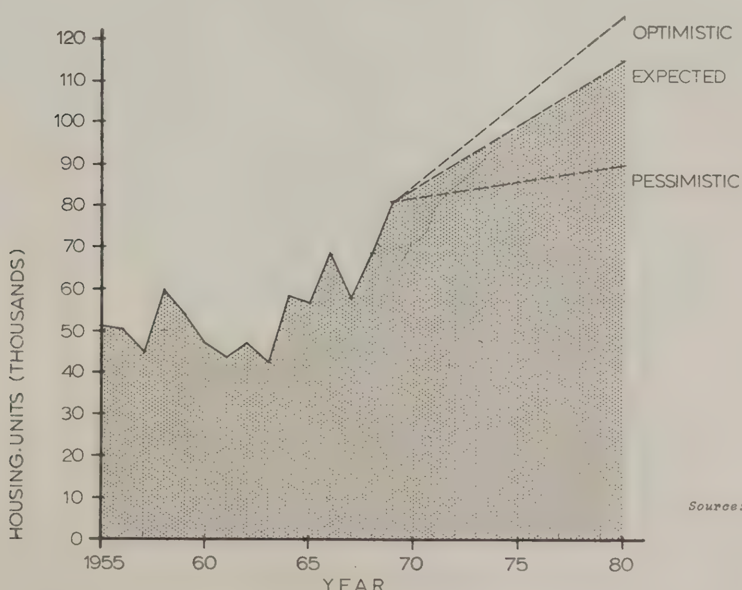
REQUIREMENTS WILL CONTINUE TO GROW

The next decade will be characterized by a significant increase in the requirements for housing. A large rise in the number of marriages and formation of non-family households as a consequence of the changing age structure of the Ontario population are the principal contributors.

Results: One million new units by 1980.

Under expected conditions, the number of dwelling units required will increase from the 1961-66 average annual completion rate of 52,000 units to 82,000 in 1970, 102,000 units in 1975 and 115,000 units by 1980 (Figure B.1). Under pessimistic conditions,

ONTARIO HOUSING REQUIREMENTS WILL CONTINUE TO GROW OVER THE NEXT DECADE



Source: Ref. 24, Peter Barnard Assoc.

FIG.B.1

the 1980 rate could drop by 23% to 89,000 units, mainly as a result of a reduction in non-family household formations. Under optimistic conditions, the 1980 rate could rise by 8% to 124,000 units. Finally, it is interesting to note that during the next decade, Ontario is expected to account for 1.0 million units or approximately 42% of the total Canadian requirement [28] of 2.4 million. This compares with 39% during the 1960s.

<u>Basic Procedure</u>

To arrive at our range of estimates to 1980, we utilized the following general three step procedure:

1. Individual components of new housing requirements for Ontario were related to the all-Canada data for the period 1951-68. As Ontario accounts for a large portion of the total, a historical relationship appeared reasonable.
2. This relationship, together with the ECC all-Canada estimates by components were used to obtain the projected individual Ontario components with adjustments as appropriate to reflect recent developments.
3. The various assumptions underlying the Ontario forecast were modified to obtain a range of results.

The future requirements for housing will largely depend on the possible sources of houshold formation of which the major components are family formation, non-family household formation and a reduction in lodging families. Other factors, such as sufficient vacancy to allow for mobility among dwellings and net replacement to the housing stock, are also a source of demand for new housing units.

Thus, our projections are based on the formula [28] that

new household requirements = net family formation + net non-family household formation + net undoubling + additional frictional vacancies + net replacements.

Net Family Formation

The basic formulas used to calculate net family formations are as follows: [27]

1. Stock of families at end of year = stock at beginning of year + net family formation during year.
2. Net family formation = marriages — deaths of married persons — divorces + net migration of families.
   - Marriages - this is the most important component of net family formation. To obtain the expected annual number of marriages for Ontario:
     1. the ratio of marriages to the total population during the years 1951-68 for Ontario and Canada were related;
     2. In addition, the ratio of marriages to population for Canada were calculated for the forecast period to 1980 based on the CMHC estimates and the DBS population projections;
     3. Based on the historical relationship the ratio of marriages to total population for Ontario were obtained for the individual years up to 1980 and then translated into actual marriages from the population projections provided by the Ontario Department of Treasury and Economics.

     Throughout the period 1956-61 and 1961-66 the number of annual marriages averaged approximately 46,000 and 48,000 respectively. [24] During the next decade the number of

marriages is expected to increase significantly from the estimated 1970 level of approximately 67,000 to 82,000 in 1975 and 94,500 by 1980. (Table B.1)

- Deaths of Married - It is assumed that each death of a married person represents a deduction from the stock of families.[27] During the period 1951-68, the deaths of married persons have been increasing steadily with little variation at the approximate average annual rate of 1.8%.[39] This rate of increase was assumed to continue for the next decade. It is interesting to note that the projections developed by the same technique as used in marriaged yielded nearly identical results. Thus, we expect the deaths of married persons to increase from an annual average of 25,800 during the last decade to 33,200 in 1980 (Table B.1).

TABLE B.1

FORECAST OF NET FAMILY FORMATION FOR ONTARIO

EXPECTED CONDITIONS (THOUSANDS)

YEAR	MARRIAGES	DEATHS OF MARRIED	DIVORCES	NET MIGRATION OF MARRIED FEMALES	NET FAMILY FORMATION
1971	69.5	28.8	4.8	16.5	52.4
1972	72.5	29.2	5.0	16.5	54.8
1973	75.0	29.8	5.1	16.5	56.6
1974	78.0	30.2	5.2	16.5	59.1
1975	82.0	30.7	5.4	16.5	62.4
1976	84.0	31.2	5.5	16.5	63.8
1977	86.0	31.7	5.7	16.5	65.1
1978	88.5	32.1	5.8	16.5	67.1
1979	91.5	32.6	6.0	16.5	69.4
1980	94.5	33.2	6.1	16.5	71.7
	821.5	309.5	54.6	165.0	622.4

Source: Refs, 24, 35, 39 Peter Barnard Assoc.

- <u>Divorces</u> - Each divorce is assumed to represent a reduction from the stock of families.[27] During the recent past the country's divorce laws have been liberalized, permitting a much larger increase in the number of divorces than was reflected in the historical data. While it is still too early to evaluate the impact of this change, the initial results indicate that an increase over the forecast period is likely. Thus, we expect the number of divorces to increase from the 1961-66 average of 3,500 to 4,600 in 1970, 5,400 in 1975 and 6,100 by 1980 (Table B.1).
- <u>Net Migration of Families</u> - This component is measured and projected on the basis of the number of married female immigrants.[27] The net migration of families decreased form an annual average of 14,000 in the early 1950s to 10,000 during the early 1960s with an increase fo 17-19,000 during the period 1966-69.[39] Based on this trend during the 1960s, our assumption about a continuing favourable economic climate and to be consistent with the net migration assumptions in the Ontario population forecast, we have used an average annual net migration level of 16,500, during the next decade. It is important to note that the CMHC forecasts for all Canada to 1981 project an average annual net migration of this same amount, 16,500, despite an actual annual rate of 22,000 during the last decade and 31,000 during the last five years.[24] Although they recognize that the assumption appears unduly conservative, they retained it for consistency with the DBS population projections.

Non-Family Household Formation

The annual non-family household formation is obtained from the annual difference in the total number of non-family households. To obtain the expected number of non-family households for Ontario to 1980, a three-step procedure was undertaken as follows:

1. The ratios of non-family households to total families during the period 1951-66 for Canada and Ontario were related;
2. Based on this relation and the projected ratio of non-family households to total families for Canada, the Ontario ratio was obtained for the required periods to 1980;
3. This data was then translated into the total number of non-family households after calculating the projected annual number of families from the previous section.

Since 1951, non-family household formation has become an increasingly important segment of total housing demand. The ratio of non-family households to total families has increased from 13.2% in 1951 and 14.4% in 1961, to 17.2% in 1966. Based on our analysis we expect this percentage to increase further to 22.6% in 1975 and 25.0% in 1980, for an annual figure of 25,000 and 26,200 respectively. (Table B.2)

Undoubling

To arrive at the expected number of families not maintaining their own households to 1980, the same general procedure was followed as in the previous section. Accordingly, the annual requirements to accommodate this undoubling is obtained from the annual difference in lodging families.

TABLE B.2

FORECAST OF ONTARIO HOUSING REQUIREMENTS TO 1980

EXPECTED CONDITIONS (THOUSANDS)

YEAR	NET FAMILY FORMATION	NON-FAMILY HOUSEHOLD FORMATION	UNDOUBLING	CHANGE IN VACANCIES	NET REPLACEMENTS	COMPLETIONS
1971	52.4	22.0	3.6	2.6	6.9	87.5
1972	54.8	23.0	3.5	2.7	7.5	91.5
1973	56.6	23.5	3.4	2.8	8.2	94.5
1974	59.1	24.0	3.4	2.8	8.7	98.0
1975	62.4	24.5	3.2	2.9	9.1	102.1
1976	63.8	25.0	3.1	3.0	9.5	104.4
1977	65.1	25.3	2.8	3.2	9.9	106.3
1978	67.1	25.8	2.5	3.3	10.3	109.0
1979	69.4	26.0	2.4	3.4	10.7	111.9
1980	71.7	26.2	2.3	3.5	11.1	114.8
	622.4	245.3	30.2	30.2	91.9	1020.0

Source: Refs. 24, 35, 39 Peter Barnard Assoc.

Since 1951, the ratio of lodging families to total families has steadily declined from 12.3% in 1951 to 4.9% in 1966. As the economic assumption underlying the forecast of housing requirements assumes full employment and steady rate of growth in GNP (5% to 5.5%), it appears reasonable to assume that a sufficient demand for housing space will be generated to permit the undoubling process to continue. Thus, we have estimated that the extent of undoubling will continue to decrease from the 1961-66 annual average of 5,100 to 3,200 in 1975 and 2,300

in 1980, by which time we expect only 1.2% of the families will not maintain their own households (Table B.2).

<u>Vacancies</u>

Over the long term the ratio of vacancies to occupied dwellings appears likely to remain within narrow limits to allow for the normal household mobility and property transfer. This ratio has grown slowly from 2.3% in 1951 to 3.4% in 1966 and is expected to average approximately 3.5% over the next decade. It is important to note that this rate does not account for short-term fluctuations or geographical differences as over the long term the market should tend in general to equal the supply of, and demand for housing (Table B.2).

<u>Net Replacements</u>

The allowance for the replacement demand is based on the fact that a certain amount of construction is required each year to maintain the existing stock of dwellings. Thus, this need for net replacement is related to such factors as the age and condition of the housing stock, together with the rate of conversions, demolition, abandonment and accidental destruction.

The CMHC projection for Canada to 1981 indicates that annual net replacements as a percent of the occupied dwelling stock will increase from an average of 0.21% for the period 1961-66 to 0.35% by 1980. Based on these forecasts, we have estimated that the annual net replacement for Ontario will increase from the 1961-66 annual average of 3,600, to 9,100 in 1975 and 11,100 in 1980 (Table B.2).

Range of Forecasts - Optimistic & Pessimistic

To assist OHC management in understanding the range of possible results and the sensitivity of the estimates to various assumptions, both pessimistic and optimistic forecasts were prepared. More specifically the alternative assumptions by the individual components of housing requirements as follows:

	Optimistic	Pessimistic
o Marriages	no change	lower population estimates
o Deaths of Married	no change	no change
o Divorces	no change	trend rate of last four years
o Net Migration of Families	trend rate of last four years	lower population estimates
o Non-family Household Formation	no change	ratio of non-family households to families held constant at 1970 estimate of 20.2%
o Undoubling	lodging families reduced to nil by 1980	ratio of lodging families to total families held constant at 1970 estimate of 3.26%
o Vacancies	5% of total occupied dwellings	2.5% of total occupied dwellings
o Net Replacements	no change	ratio of net replacements to total occupied held constant at 1961-66 level of 0.22%

The actual results by components under all three conditions for the next decade are illustrated in Table B.3.

TABLE B.3

COMPONENTS OF TOTAL HOUSING REQUIREMENTS
TO 1980
OPTIMISTIC AND PESSIMISTIC CONDITIONS

(THOUSANDS)

	OPTIMISTIC	EXPECTED	PESSIMISTIC
MARRIAGES	821.5	821.5	805.3
DEATHS OF MARRIED	309.5	309.5	309.5
DIVORCES	54.6	54.6	61.5
NET MIGRATION OF FAMILIES	210.0	165.0	124.0
NET FAMILY FORMATION	667.4	622.4	558.3
NON-FAMILY HOUSEHOLD FORMATION	245.3	245.3	127.0
UNDOUBLING	53.0	30.2	20.0
VACANCIES	45.0	30.2	20.4
NET REPLACEMENTS	91.9	91.9	58.0
TOTAL REQUIREMENTS	1102.6	1020.0	783.7
AVERAGE ANNUAL RATE	110.3	102.0	78.4

Source: Refs. 24, 35, 39 Peter Barnard Assoc.

It is interesting to note that the 10 year estimate of completions ranges from a low of 784,000 units under pessimistic conditions to a high of 1,102,000 units under optimistic conditions. This is equivalent to a spread of 32,000 in the average annual rate, from a high of 110,000 to a low of 78,000 units.

REQUIREMENTS CONCENTRATED AROUND TORONTO

During the five year period 1965-69, the population of Ontario increased by approximately 820,000 and the number of completions totalled nearly 300,000 for an average of 36

dwellings per 100 increment in the population. The Lake Erie and Mid-Western regions had the highest ratios of 47% and 44% respectively, followed by Central Ontario and the Niagara regions with 41% and 40% respectively (See Figure B.2 for location of regions).

Results - 75% Within 100 Miles of Toronto

During the next decade to 1980, the provincial population is expected to increase by approximately 1.5-million to 9.1 million, with a substantial increase in the number of dwellings per 100 increase in the population to 67. We forecast that Central Ontario, Niagara and Eastern regions will have the largest number of completions (627,000,105,000 and 104,000 respectively) followed by Lake Erie, Mid-West and Lake St. Clair with 59,000, 51,000 and 39,000 respec-

FIG. B.2

Source: Ref. 35, Peter Barnard Assoc.

tively (Table B.4). Finally, our estimates indicate that approximately 75% or 765,000 units will be built within 100 miles of Toronto compared to approximately 65% or 400,000 units during the last decade.

Basic Procedure

To arrive at a forecast of requirements by economic regions to 1980, we used the following procedure:

1. The historical dwelling completions by the ten economic regions as defined by the Ontario Government Department of Trade and Development were obtained for the period 1965-69 and related to the population growth for the same period to obtain completions per 100 increase in population;
2. The most recent population projections by economic regions prepared by the Ontario Department of Treasury and Economics to 1981 were used to calculate the expected changes in population for the next decade;

TABLE B.4

FORECAST OF COMPLETIONS BY ECONOMIC REGION

(THOUSANDS)

ECONOMIC REGION	ACTUAL 1965-69 - 5 YEARS: TOTAL COMPLETIONS	ACTUAL 1965-69 - 5 YEARS: TOTAL POPULATION GROWTH	ACTUAL 1965-69 - 5 YEARS: AVERAGE ANNUAL COMPLETIONS PER 100 INCREASE IN POPULATION	FORECAST 1971-80: POPULATION GROWTH NO.	FORECAST 1971-80: POPULATION GROWTH %	FORECAST 1971-80: PRELIMINARY COMPLETIONS	FORECAST 1971-80: FINAL COMPLETIONS	FORECAST 1971-80: AVERAGE ANNUAL COMPLETIONS PER 100 INCREASE IN POPULATION
EASTERN	30.5	80.0	38	159.0	10.4	106.1	104.0	65
LAKE ONT.	4.6	35.0	13	48.0	3.1	31.6	7.2	15
CENTRAL ONT.	164.1	397.0	41	796.0	52.0	530.4	627.4	79
NIAGARA	37.8	95.0	40	156.0	10.1	103.0	105.0	68
LAKE ERIE	16.5	35.0	47	79.0	5.2	53.0	59.0	75
LAKE ST. CLAIR	13.6	50.0	27	96.0	6.3	64.3	38.6	40
MID-WESTERN	17.8	40.0	44	85.0	5.5	56.1	51.0	60
GEORGIAN BAY	2.8	23.0	12	32.0	2.1	21.4	4.8	15
NORTH-EASTERN	7.9	46.0	17	67.0	4.4	44.9	20.2	30
LAKEHEAD - N.W.	3.1	20.0	16	14.0	.9	9.2	2.8	20
	298.7	821.0	36	1532.0	100.0	1020.0	1020.0	67

Source: Refs. 24, 35, Peter Barnard Assoc.

3. A preliminary estimate of the number of completions by economic region was calculated by applying the ratio of the total population growth to the overall housing requirement projections to 1980;
4. These preliminary projections were adjusted in consideration of the historical completions per 100 increase in the population, the overall population growth and the concentration of this population within the various urban areas.

We recognize the weaknesses of this approach compared to a detailed component analysis by economic regions similar to the technique used for the province. However, to establish the economic regions of major growth and provide a meaningful indication of the market size that would be available to support a local system building industry, we considered it appropriate to short circuit the more rigorous analysis and rely on macro growths and shifts in population tempered by the past relationship between completions and population increases.

MAJOR GROWTH WILL CONTINUE TO BE IN MULTIPLE UNITS

During the past decade, requirements for single-family dwellings has remained reasonably stable while multiples have shown marked increases.

Results - Multiples will Account for nearly 60% by 1980

It appears likely that the requirements for single-family dwellings which has remained reasonably stable during the period 1961-69, will strengthen and gradually increase from the 1969 level of approximately 37,000 units

or 45% of the total to 48,000 units or 42% by 1980. Multiples are expected to rise more quickly from 44,000 or 55% in 1969 to 67,000 to 58% in 1980, with the low-rise, medium-density housing component increasing from 5,000 to 14,000 by 1980. (Figure B.3)

Basic Procedure

To arrive at our forecast of requirements to 1980, by types of dwellings, we used the following three-step procedure:

1. Past trends of completions by types were reviewed and related to past changes in the age structure of the population;
2. Based on this analysis and the expected changes in the age profiles of the population to 1980, the single-family component was projected with the balance allocated to multiple dwellings;

REQUIREMENTS FOR MULTIPLES WILL CONTINUE TO DOMINATE

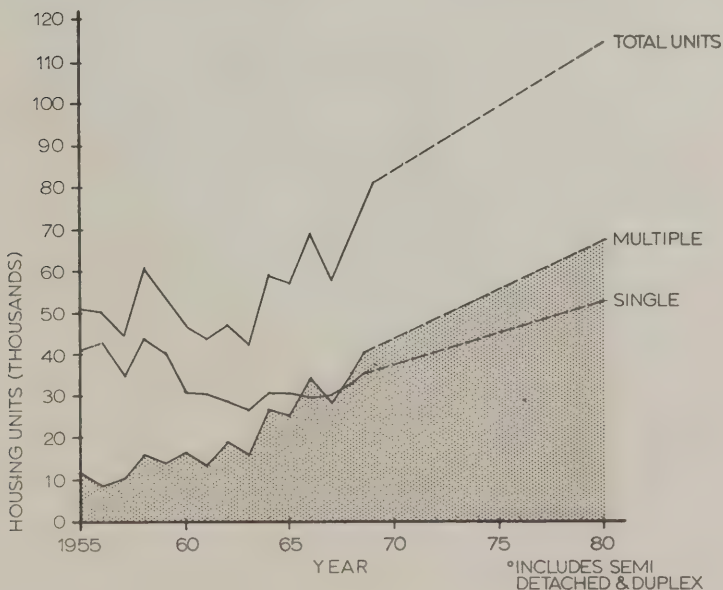


FIG. B.3

Source: Ref. 24, Peter Barnard Assoc.

3. The results were compared to the all-Canada projections prepared by CMHC.[28]

Changes in the tenure preference of the population depend primarily upon the age and marital status of the population, together with economic considerations.

The expected changes in the age structure of the Ontario population suggests a strengthening in the demand for home ownership during the next decade. As shown in Table B.5, during the 1961-66 period the population in the 25-34 age group, which accounted for 44% of all the NHA home borrowers in 1967, remained nearly unchanged, while there was a marked increase in the younger and older age categories. This trend appears to have been a major factor contributing to the dramatic shift towards construction of multiples during the same period. During the next decade the 20-24 group is projected to grow, but at a lower rate than the 1961-71 period. At the same time, the population

TABLE B.5

FORECAST OF POPULATION GROWTH BY AGES

(THOUSANDS)

AGE	NHA BORROWERS FOR CANADA IN 1967	POPULATION GROWTH ACTUAL 1951-56	ACTUAL 1956-61	ACTUAL 1961-66	EST. 1966-71	FORECAST 1971-76	FORECAST 1976-81
UNDER 20	7.8%						
20-24	25.6%	12.8	21.8	98.1	161.3	113.6	104.1
25-29	24.2%	30.2	5.3	11.2	90.2	160.6	113.1
30-34	19.2%	87.7	21.1	-12.7	29.3	108.2	159.9
35-39	11.3%	50.0	78.5	3.3	.9	29.1	107.3
40-44	6.6%	58.8	36.2	72.0	17.2	1.1	29.0
45-49	5.3%	44.1	48.6	30.2	81.9	17.2	1.3
50-54	5.3%	21.8	40.5	43.6	34.8	79.9	16.9
55-59	5.3%	26.2	21.8	35.0	51.0	33.8	76.7
60-64	5.3%	11.6	21.7	25.6	34.0	47.8	32.1
65 +	5.3%	54.0	53.6	59.7	59.0	75.0	95.5
TOTAL	100.0	397.2	349.1	366.0	559.7	666.3	735.9

Source: Refs. 35, Peter Barnard Assoc.

in the home buying category is expected to rise rapidly, which should increase the demand for single dwellings.

Whether or not this increased demand for single dwellings will occur will depend to a great extent on the relative costs of single vs multiples. Recent data suggest that single detached housing is beyond the reach of the bulk of the population (see Part 3). If current cost trends continue it appears that the theoretical demand for single family dwellings created by demographic factors may not be able to fully express itself in the market. Secondly, it seems that this unsatisfied demand will increase the need for structures similar to row and other forms of medium-density, low-rise housing. In addition, it appears likely that this unsatisfied demand will increase the requirement for apartments. These factors have been considered in arriving at our forecast.

4. OHC MARKET ESTIMATES TO 1980

Projections of OHC requirements are particularly difficult because of a number of complicating factors. Principal among these is the lack of a clearcut definition of the "consumer" in the public housing programs. Furthermore, OHC's building program is very much affected by the availability of Federal and Provincial funds.

To assess probable market size, we have first adopted a simplified definition of the consumer in consultation with OHC staff members. We then prepared forecasts for the total market to 1980 (i.e., the total number of low-income family "consumers" in the province in 1980). The desired level of penetration into this market by OHC is a matter of policy and availability of funds. However, to give an indication of the magnitude of possible OHC building programs, we present estimates of the annual number of units, given various OHC penetration objectives.

LOW-INCOME FAMILY HOUSING

This program currently accounts for the bulk of OHC building construction.

Consumer

Based on a rough analysis of tenants, it was generally agreed with OHC personnel that the major market is comprised of all families with heads under 65 years of age who are spending a disproportionate share of their income on food, shelter and clothing. It is important to note that individuals and non-family households are not included.

Results

Our calculations indicated that OHC's share of this particular market as at June, 1970 totalled approximately 12% or 27,000 units. As the desired level of penetration is a matter of policy and availability of funds, we have calculated the various levels of production required to reach a given range of penetration objectives. As shown in Table B.6, in order to reach a level of 25% by 1980, approximately 3,000 units on the average will have to be built each year. Similarly, to satisfy 50%, 75% and 100% of this market it will be necessary to undertake a program providing for 9,000, 15,000 and 21,000 units annually to 1980.

FAMILY RENT-GEARED-TO-INCOME

(THOUSANDS)

TABLE B.6

ADDITIONAL UNITS REQUIRED TO REACH VARIOUS MARKET SHARES BY 1980

(THOUSANDS)

ALTERNATIVE PENETRATION BY 1980	TOTAL NUMBER OF UNITS REQUIRED	TOTAL ADDITIONAL UNITS REQUIRED BY 1980	AVERAGE ANNUAL PRODUCTION TO REACH REQUIRED MARKET SHARE BY 1980
25%	58	31	3.1
50%	116	89	8.9
75%	173	146	14.6
100%	232	205	20.5

Source: Refs: Peter Barnard Assoc.

Basic Procedure

Our procedure for projecting this market involved the following six steps:

1. The number of families in Ontario with heads under 65 years of age were projected. This estimate is based on the all-Canada forecast of families by age of heads (Table B.7).
2. The average number of members per family was estimated over the next decade based on trends since 1941.
3. We calculated the income level below which more than 70% of the gross family income (according to projected family size) would be spent on the basic necessities of life (Table B.8). This family "financial assistance level" was based on calculations made by the DBS [30] for the ECC.
4. An estimate of the income distribution of families in Ontario in constant 1961 dollars was prepared (Table B.8). These estimates are based primarily on historical trends during the period 1951-65 projected with the aid of the Lorenz curve technique.

TABLE B.7

FAMILIES AND NON-FAMILY HOUSEHOLDS FOR CANADA AND ONTARIO BY AGE

(THOUSANDS)

	ACTUAL				ESTIMATED	PROJECTED
CANADA	1951	1956	1961	1966	1970	1980
TOTAL FAMILY	3287	3712	4147	4526	4916	6377
NON FAMILY	459	523	666	853	1050	1623
LESS THAN 65 - FAMILY	2861	3233	3631	3975	4320	5650
- NON FAMILY	286	318	404	526	682	1055
AGE 65-80 - FAMILY	363	404	430	454	482	601
- NON FAMILY	147	172	218	269	310	468
% OF FAMILIES LESS THAN 65	87.0	87.0	87.5	88.0	88.1	88.5
% OF FAMILIES AND NON FAMILIES 65-80	14.0	13.6	13.4	13.4	13.3	13.4
ONTARIO						
TOTAL FAMILY	1163	1343	1512	1658	1807	2478
NON FAMILY	154	161	218	285	365	624
NO. OF FAMILIES UNDER 65	1010	1165	1310	1460	1550	2190
NO. OF FAMILIES AND NON FAMILIES 65-80	185	205	232	260	289	415
NO. OF FAMILIES UNDER 65 REQUIRING FINANCIAL ASSISTANCE	1010	1165	1310	1460	1550	232
NO. OF FAMILIES AND NON FAMILIES 65-80 REQUIRING FINANCIAL ASSISTANCE	--	--	143	133	141	146

Source: Refs. 24, 28, 34 Peter Barnard Assoc.

TABLE B.8

CALCULATION OF FINANCIAL ASSISTANCE LEVEL FOR AVERAGE FAMILY

SIZE OF FAMILY	ASSISTANCE LEVEL (1961) ($000)	PROJECTED ASSISTANCE LEVEL FOR AVERAGE HOUSEHOLD SIZE OF 3.6 ($000)
1 PERSON	1.5	
2	2.5	
3	3.0	$3.3
4	3.5	
5+	4.0	

% INCOME DISTRIBUTION - ONTARIO FAMILIES 1951-80 IN 1961 CONSTANT DOLLARS

1961 CONSTANT DOLLARS (PERCENT)

INCOME CATEGORY (THOUSANDS $)	1951	1954	1957	1959	1961	1965	EST 1970	PROJECTED 1980
UNDER 1.0	4.5	2.5	3.5	1.9	2.0	2.0	2.0	1.5
1.0 - 1.9	8.5	5.7	8.0	6.5	5.3	4.6	4.0	3.0
2.0 - 2.9	14.9	10.9	11.1	8.6	8.4	6.1	5.7	4.5
3.0 - 3.9	23.9	19.9	14.7	13.1	10.6	8.7	6.5	5.3
4.0 PLUS	48.2	61.0	62.7	69.9	73.7	78.6	81.8	85.7
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
% BELOW FINANCIAL ASSISTANCE LEVEL					18.9	15.3	13.7	10.6

Source: Refs. 25, 30 Peter Barnard Assoc.

5. The family "financial assistance level" was applied to projected 1980 income distribution to obtain the percentage of families requiring assistance. The total number of families falling into this category was then calculated by applying the financial assistance level percentage to the projected total of Ontario families with heads under 65 in 1980 (Table B.7).

6. After ascertaining OHC's present share of this market, the additional number of units required to obtain market shares of 25%, 50%, 75% and 100% by 1980 were calculated.

LOW-INCOME SENIOR CITIZEN HOUSING

Senior citizen housing is currently OHC's second largest building program. It does not include construction of senior citizen units within Metro Toronto.

Consumer

As discussed in the previous section, based on an analysis of the existing consumer it was generally agreed with OHC personnel that the major market for this type of accommodation is comprised of all families and non-family households with heads between the ages of 65-80 who are spending a disproportionate share of their income on food, shelter and clothing.

Results

Our calculations indicated that the total market share of rent-geared-to-income, non-profit and limited-dividend housing for senior citizens as at June, 1970 totalled approximately 8% or 12,000 units. As shown in Table B.9, in order to achieve a penetration of 25% by 1980 approximately 2,400 units will have to be built annually, of which 1,200 will be built outside of the Metro Toronto area. Similarly, to reach 50%, 75% and 100% by 1980 it will be necessary to build 6,100, 9,700 and 13,400 units respectively, of which 3,100, 4,900 and 6,700 respectively will be required outside of Toronto.

Basic Procedure

To arrive at our projections of this market to 1980 a six-step procedure was followed:

TABLE B.9

SENIOR CITIZEN - RENT GEARED TO INCOME

(THOUSANDS)

ADDITIONAL UNITS REQUIRED TO REACH VARIOUS MARKET PENETRATION BY 1980

(THOUSANDS)

ALT. PENETRATIONS BY 1980	TOTAL UNITS REQ'D.	TOTAL ADD. UNITS REQ'D. BY 1980	AVER. ANNUAL PRODUCTION TO REACH REQ'D. MKT. SHARE BY 1980		
			TOTAL	METRO	EX-METRO
25%	36	24	2.4	1.2	1.2
50%	73	61	6.1	3.0	3.1
75%	109	97	9.7	4.8	4.9
100%	146	134	13.4	6.7	6.7

Source: Ref. Peter Barnard Assoc.

1. It was necessary to forecast the number of families and non-family household heads in Ontario with heads between 65 and 80 years of age. This estimate is based on the all-Canada estimates by age of heads prepared for ECC. (Table B.7).
2. We estimated to 1980 the average persons per family and non-family household within this category based on historical data since 1951 and population projections.
3. Based on this average unit, an income level was calculated below which more than 70% of the gross income would be spent on the basic necessities of food, shelter and clothing (Table B.10). This senior citizen "financial assistance level" was derived from the same ECC data as in the previous section.

TABLE B.10

CALCULATION OF FINANCIAL ASSISTANCE LEVEL FOR AVERAGE SENIOR CITIZEN FAMILY & NON-FAMILY HOUSEHOLD

SIZE OF FAMILY	ASSISTANCE LEVEL (1961) ($000)	PROJECTED ASSISTANCE LEVEL FOR AVERAGE HOUSEHOLD SIZE OF 1.7 ($000)
1 PERSON	$1.5	
2	2.5	
3	3.0	$2.2
4	3.5	
5+	4.0	

% INCOME DISTRIBUTION - ONTARIO SENIOR CITIZENS 1951-1980 IN 1961 CONSTANT DOLLARS

INCOME CATEGORY ($000)	1951	1954	1957	1959	1961	1965	EST. 1970	PROJECTED 1980
UNDER 1.0	34.3	28.6	29.6	28.3	28.7	21.7	18.0	10.0
1.0 - 1.9	24.8	25.2	29.3	27.8	26.6	26.8	27.5	20.0
2.0 - 2.9	13.9	15.0	12.8	14.2	12.7	16.7	17.0	27.0
3.0 PLUS	27.0	31.2	28.3	29.7	32.0	34.8	37.5	43.0
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
% BELOW ASSISTANCE LEVEL					57.8	51.8	48.9	35.4

Source: Ref. 25, 30 Peter Barnard Assoc.

4. A 1980 income distribution for families and unattached individuals ages 65-plus, was projected in 1961 constant dollars based on the historical trend indicated by the Lorenz curve technique, together with consideration of the increasing payments through various government programs. (Table B.10)
5. The "financial assistance level" was applied to the projected 1980 income distribution to obtain the percentage of senior citizens requiring assistance. The total number of families and non-families falling into this category was then directly calculated by applying this percentage to the total number of family and non-family households age 65-plus projected to 1980 (Table B.7).

6. We calculated the additional number of senior citizen units required by 1980 to achieve a market penetration of 25%, 50%, 75% and 100%. The particular OHC share, estimated at 50%, was then estimated by removing the Metro Toronto portion.

STUDENT HOUSING

Student housing is currently OHC's third largest building program but has been severely cut back during recent years due to reduction in Federal funds from approximately $40 million in 1968, $20 million in 1969 and $10 million in 1970. Our results show that this level of funds will be inadequate to meet future requirements assuming current concepts and cost levels for university student accommodation.

Consumer

For purposes of this study we selected the students attending universities and teacher colleges but excluded the students of other post-secondary schools, such as community colleges, technical schools and nurses residences. Although the growth rate in community colleges is expected to be high, they are intended to serve the local community and generally are not expected to require student accommodation except possibly in the low-population-density areas such as Northern Ontario.

Results

Our projections indicate that approximately 25% of university students will be provided with university-or government-financed accommodation for the 1970/71 school year, as opposed to 16% during 1965/66 and 23% during 1968/69. University enrolment will grow during the next

decade and to continue to accommodate the additional or incremental student population at the current 25% level, it will be necessary to provide approximately 4,000 new beds each year to 1980 (Table B.11). Similarly, to house 50%, 75% and 100% of the incremental student population will require 8,000, 12,000 and 16,000 beds respectively.

To provide a closer estimate of requirements we conducted a brief survey of 5 universities to determine their expected levels of requirements. Responses varied from 30% to 100% of the additional student population (i.e. all additional students would have to be housed in residences). These responses reflected the growing inability of the communities where the universities are located to provide further student rooms. Based on this rough survey, it appeared that a level of 60% of the incremental student population may be required. This would

TABLE B.11

PRODUCTION RATE OF ONTARIO UNIVERSITY BEDS REQUIRED TO ACCOMMODATE VARIOUS PERCENTAGES OF INCREMENTAL STUDENT POPULATION

(THOUSANDS)

PENETRATION OBJECTIVES FOR INCREMENTAL STUDENT POP.	REQUIRED	TOTAL ADDITIONAL BEDS REQUIRED	AVERAGE ANNUAL PRODUCTION NEEDED TO MEET OBJECTIVES	% OF TOTAL STUDENT POPULATION ACCOMMODATED
25%	69.5	38.6	3.9	25.0
50%	108.3	77.6	7.8	39.5
75%	147.1	116.4	11.6	53.0
100%	185.9	155.2	15.5	67.0
60% (PROBABLE)	123.7	93.0	9.3	45.0

Source: Ref. 26 Peter Barnard Assoc.

require a building program of 9,300 beds per year to 1980, requiring an annual expenditure of approximately $48 million at current cost levels.

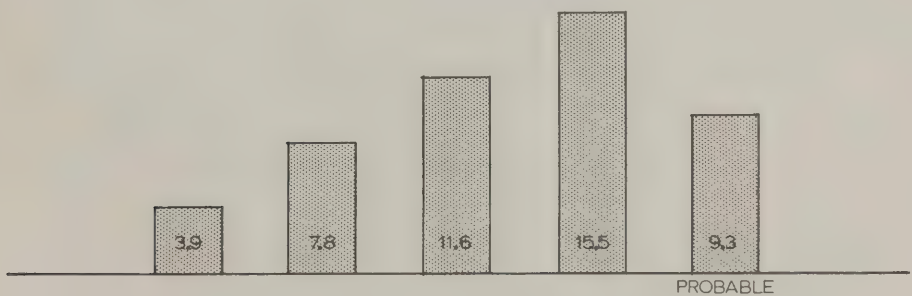
Basic Procedure

To project the size of the market for student housing a three-step program was followed:

1. It was necessary to obtain a projection of the number of students expected to attend universities by 1980/81 [26].
2. Next, we established the existing stock of beds controlled directly or indirectly by the universities and/or financed by CMHC or OHC, and thus were able to ascertain the percent of students for which beds were currently provided. The historical stock of beds to 1965 was also calculated using past CMHC statistics [24].
3. The additional number of beds was calculated to accommodate 25%, 50%, 75% and 100% of the incremental student population by 1980/81.

AVERAGE ANNUAL PRODUCTION OF ONTARIO UNIVERSITY BEDS REQUIRED TO ACCOMMODATE VARIOUS PERCENTAGES OF INCREMENTAL STUDENT POPULATION

1970-1980
(IN THOUSAND BEDS)



%PENETRATION OF INCREMENTAL STUDENT POP.	25%	50%	75%	100%	60%
%PENETRATION OF TOTAL STUDENT POP.	25	39	53	67	45

FIG. B.4

Source: Ref. 26, Peter Barnard Assoc.

APPENDIX C: NEW MATERIALS AND PRODUCTS

As part of our study, an investigation into new materials and products was undertaken to determine their potential influence on system building. Some of the information it yielded is reflected in the main body of the report. A more detailed review is contained in this Appendix.

METHODOLOGY - A SURVEY OF BUILDING MATERIALS ASSOCIATIONS

To conduct this study, building materials associations were solicited by personal contact and a questionnaire. They were requested to distribute the questionnaire to their members, collect and analyse the returns, and prepare a concise brief based on these responses. Where there was special reason to do so (e.g. knowledge of development work being done on some new product) we made direct contact with individual manufacturers.

Synopsis of Questionnaire

Purpose - to obtain a forecast of new building products and materials that could be available to the Ontario Housing Corporation next decade and could have a bearing on the development of system building in the Province.

Time - i) present to 1973 ii) after 1973

Scope - To be concerned with:

a) products incorporating new uses of existing materials;

b) products made of materials possessing new properties.

Describe under following headings where appropriate:

Categories - 1. Structural components
2. Non-structural components
3. Fittings and Services
4. Finishes

Benefits - Purchase price) for owner
Installation cost) user
Maintenance cost) builder
Performance) subcontractor

Constraints - Building Codes
Volume of Production
Transportation distance
Special equipment and skills needed
New distribution channels

Responses

We received briefs or conducted interviews concerning the following materials: adhesives and sealants, asbestos, brick, concrete, paints, plastics, steel and wood. The content of the responses was above our expectation, particularly in the cases of plastics and concrete. We are most grateful to all those concerned for their time and effort.

In the detailed reports that follow this introduction we have omitted parts of some briefs (such as a section describing certain concrete building systems and another discussing recent changes to the brick design portions of the National Building Code). In other cases we have added comments and made minor editorial changes. Apart from this, the reports are presented essentially as they were submitted to us.

NEW MATERIALS AND PRODUCTS - SUMMARY OF CONCLUSIONS

In this investigation we were concerned equally with totally new materials (such as some of the plastics), new products (by which we mean proprietary or manufactured items such as plumbing fixtures, hardware, windows etc.), and new ways of using existing materials (such as some of the wood treatments).

New versus traditional materials

The building industry tends to use a high proportion of traditional "commodity" materials (such as lumber, brick, cement and plaster) in the structure, and more innovative "specialty" products (such as plastic laminates, resilient flooring, pre-hung doors, etc.) in the finishing.

With the notable exception of plastics in recent years, innovation has tended to come from new combinations of materials or in ways of finishing or joining old materials. We would expect this pattern to continue. Certainly we detect no imminent major material "breakthrough". Even if one existed, it would be a carefully guarded secret of the manufacturer concerned.

Thus, in the near future we would expect the majority of building systems to continue their present pattern of using traditional structural materials in new ways, rather than to introduce radically new materials. For example, it is worth noting that only two or three of the 22 winners in HUD's "Operation Breakthrough" propose really innovative structural uses of materials (e.g. TRW's core-wound fibreglass shells, and Materials System Corporation's molded resin panels). Primary application of new materials will continue to be in finishing.

Substitutions of products

It is interesting to note that many of the most commercially successful new products of recent years have been substitutions of one item for another. Examples are the use of steel studs instead of wood, plastic-laminated wallboard instead of panelling or wallpaper, gypsum drywall instead of wet plaster, prefinished siding instead of painting. None of these makes any basic change to the way a house or apartment is built. In the same way, the system builder may be expected to search for products better suited to his factory production techniques than those used in traditional building.

Plastics and concrete are promising

We believe that plastics, in some form, appear to be the materials most likely to make an innovative contribution to the building industry — both system and conventional — during the next decade. Composites of plastics are ideally suited to such applications as the complex molded forms that are being proposed for some building systems.

Concrete, on the other hand, is a good example of a traditional material being refined in several ways to give more flexibility. Concrete has now been used for system building to such an extent that it has a head start on research and development closely related to system applications.

A. PLASTICS

It has been said that the '50s and the '60s were the decades of the plastics and that the '70s will be the decade of the composites. This means new combinations of presently available materials that will have greatly improved physical properties. Whereas fillers, such as clay, were added to plastics to extend them or cheapen them, we now add fibres of other types of reinforcement to improve the plastic's physical properties. The improved product is no longer just a plastic; it is a composite material.

Composite materials may contain components that improve the strength, stiffness, non-flammability, hardness and heat distortion properties which are the main weaknesses of plastics. Because of the low density of composite materials, self-contained complete products and assemblages can be fabricated that are readily installed and trouble-free.

A recent market survey by 'Modern Plastics' magazine indicates that the annual consumption of plastics in 1980 will be 200% to 300% greater than in 1970 and this will be mainly at the expense of glass, aluminum, steel, zince and stone.

Some indication of why plastics and composites will replace these other materials is shown in Table 1 where significant properties of present plastics, reinforced plastics, and high performance composites, are compared.

Table C.1: Properties of building materials

Property	*Plastics*	*Reinforced Plastics*	*High Performance Composites*
E (psi)	$.1-.5 \times 10^6$	$1-5 \times 10^6$	$5-15 \times 10^6$
σ (psi)	$5-20 \times 10^3$	$10-30 \times 10^3$	$10-50 \times 10^3$
Heat distortion temperatures ($^{\circ}$f)	100-300	200-500	300-800
Flammability	high	medium	low
Coeff. of expansion	10^{-4}	10^{-5}	10^{-5}
Creep under load	high	medium	low
S-G	.9 - 1.5	1 - 2	2 - 3
Mechanical properties	isotropic	anisotropic	anisotropic
Smoke developed	high	medium	low
Cost/lb (1970)	.10 - 1.00	.30 - 1.50	.50 - 5.00

The following categories are each divided into two: 'present' and 'future'. 'Present' refers to plastic products currently available in the marketplace, with indications of likely modifications up to 1973. 'Future' describes items of the post-1973 era. Even though some of these could be made today, environmental testing to the builder's satisfaction has to be done and code acceptances obtained, and therefore it is felt that they will not reach the marketplace until after 1973.

Structural components: present

At the present time, plastics are not used very extensively in housing structures.

Reinforced-plastic structural beams are now available in commercial quantities from certain steel suppliers in the U.S. This application is involved mostly in corrosion-resistant applications in chemical and steel plants. One or two firms in Canada are producing structural beam components. Their pricing so far is out of line for use in housing.

A Toronto firm has developed a system of portable buildings mainly used by utility and energy companies in the northland and remote areas where it is difficult to bring in construction supplies. This is a series of prefabricated buildings made of a sandwich system of reinforced plastic and urethane panels, interlocked and slid together with very few bolts, which can be flown to the job site and used for buildings, for housing standby engines and power equipment, for powering radar, communications installations and such purposes.

At Frobisher Bay, a $2.7-million plastic-enclosed high school is currently being erected. The two-storey school will contain 73,500 sq. ft. and will be enclosed by prefabricated panels made of glass reinforced polyester bonded to urethane foam. The 14-ft. x 7-ft. panels are only 2 inches thick and weigh less than 160 pounds. The panels are being manufactured by a firm in Renfrew, Ont.

Pressure for new building concepts(especially the system concept) will be based on the use of prefabricated plastics panels. This work is now upon us and should be fully developed by the '80s. The building shell comprising

floors, walls, roof, complete with doors and windows and a light foam insulation; and concepts like one-piece bathrooms and kitchens will be the prime focus of activity.

Watch for low-cost mass housing based on plastics. The entry of large organizations and conglomerates into the building system business will hasten this activity. At the present time, plastics have very little place in the foundation of houses, although there is a great deal of work being done in the introduction of plastics into concrete and cement construction. Plastics are playing an increasing part in perimeter insulation and foundation insulation around the periphery of a building with the use of styrene foam insulation and the use of filler for concrete floor underlay insulation.

Structural components: future

Whole rooms can be filament wound, forming a sandwich structure of two filament-wound skins covering a foam core. At present, the foamed core would be made of polyurethane or polystyrene foam. In the future, this will likely be an inorganic foam - which would decrease the amount of combustible material used in the structural components.

4-ft. x 8-ft. sandwich panels made of composite materials will have skins made from high performance composites and a core of reinforced inorganic foam.

Box, circular and channel cross-sections can be pultruded from continuous glass fibres that are coated with a resin and then pulled through a forming die. These beams have moduli of 5-6 x 10^6 psi and tensile strengths of 200 - 400 x 10^3 psi. With a specific gravity of about 2, these sections have strength-to-weight ratios and stiffness-to-weight ratios comparable to steel and can therefore be considered as structural columns and beams.

Non-structural components: present

There are at least two Canadian suppliers of exterior vinyl cladding for houses and buildings. Two or three other companies are on the point of introducing vinyl cladding. This, coupled with imports from two major producers in the United States, is broadening and expanding the market for vinyl.

In interior partitions, development of modular assemblies using plastic facings with foam cores is under way. Various apartment buildings in Canada and such buildings as the Carlton University Library in Ottawa have polyester-faced panels on the exterior and, in some cases, on the interior.

Vinyl materials for interior application over plywood and other types of panelling are making great progress.

The built-up roof presents a dramatic opportunity for polymers to solve the age-old problem of leaking. New single-membrane types, like butyl rubber and chlorosulfonated polyethylene are making progress. Most built-up roofs are insulated too; there is a wide and increasing use of both styrene and urethane foam at one pound density and average thickness of 2" that is taking up large volumes of plastic foam insulation.

The extensive use of plastics for staircases is questionable. That is, in the staircase itself; although plastics have been used for decorative effects in various types of see-through stairways for higher-priced houses. But there has been very extensive use of vinyl coverings on hand rails and balcony railings in many buildings.

Interior door frames, panels, sliding doors, folding doors and urethane foam-filled doors are all available in the Canadian market. The all-vinyl window and the wood sash and frame covered with vinyl are readily available and meeting an increasing demand. Acrylic skylights, reinforced plastic skylights and vacuum-formed PVC ceiling panels are readily available on the Canadian market.

Non-structural components: future

PVC siding as currently used suffers from two defects: it creeps and sags, and expands and contracts greatly. These two deficiencies could be overcome by using PVC reinforced with glass fibres. The composite would have a much higher elastic modulus and a much lower coefficient of expansion.

Using high performance composite skins and an inorganic foam core, sandwich panel doors could be made with attractive fire-resistant and noise-reducing properties, as well as being easily prefabricated and of light weight.

Strong, dimensionally-stable, impact-resistant windows and frames could be completely assembled for installation using glass-fibre reinforced PVC extrusions for the frame and glass-fibre reinforced acrylic sheet for glazing.

Pultruded channels would be strong and stiff enough to be used for railings on stairs in houses and outside balconies on apartments. The panels used to fill in the spaces between the structural railings and their supports could be injection-molded reinforced thermoplastics shaped either as panels or in more decorative intricate repeating shapes. Whole assemblies could be prefabricated and the light-weight structures installed complete.

<u>Fittings and services: present</u>

Kitchen, bathroom and storage facilities using ABS vacuum-formed panels are available, as are polyester laminate kitchen cabinets.

Complete reinforced-plastic bathroom units are now available from one or two suppliers in Ontario.

A full range of cultured marble reinforced bathroom units is also available from three or four sources within the province.

Today 80% to 90% of drain, waste and vent installations involve plastics (both ABS and PVC). Plastic DWV pipe has had code and CMHC acceptance for use for the past four years. It is now allowed up to a 36-foot high stack. Industry estimates are that a saving of between $100 to $120 per house can be made in such installations.

Great savings are possible through the lightness in weight and the ability to prefabricate the stack systems prior to installation.

Four companies are now producing chlorinated polyvinylchloride pipe for both hot and cold water systems which competes with copper piping. A standard is being developed for this piping material through the Canadian Standards Association. When this is developed (within the year) it should open up the use for hot and cold water systems.

Tests are currently being conducted by the National Research Council in Ottawa toward the development of a safe method of utilizing plastic piping in high-rise buildings. Tests to date have been extremely satisfactory and suggest

that in the horizontal usage of plastic piping through fire walls, it is a very safe material to use. Upon the completion of vertical testing, hopefully approvals will be given for the use of both ABS and PVC in high-rise buildings.

Currently in the United States, the Federal Housing Administration has approved the use of plastic piping in apartment buildings up to six storeys in height.

There is a fair amount of duct work for cables being installed in houses in Canada and this use should increase. Also, plastic ducting lends itself very readily to centralized dust collection systems within the home.

Fittings and services: future

At present, PVC piping suffers from too large a coefficient of expansion, sagging in long sections if unsupported, and cannot be used for hot water services. Reinforced thermoplastic pipe would have increased strength, modules and heat distortion temperatures and decreased coefficient of expansion, hence, overcoming the present plastic pipe deficiencies.

Already, there is a trend to make kitchen cabinets and drawers from plastics. Using reinforced plastics, by 1973, whole kitchen cupboard assemblies should be available. The ultimate will be complete kitchens with cupboards and drawers all part of the room, following the principles used with the Expo '67 bathrooms in Habitat where the complete bathroom was shipped as three parts nested together and installed on site by merely un-nesting and connection of the services.

Finishes:

There is an increasing use of vinyl wall coverings on both plaster, plywood and wood panel interior finish.

Plastics are beginning to compete with fibrous insulations. One can see this with gypsum board manufacturers becoming involved in the plastics industry ... firstly, by coating their gypsum board with PVC, then moving farther on into the all-plastic insulation areas.

Of all the polymers currently used in construction, over 55% take the form of coatings and adhesives; about 5% go into fixtures; 7% are pipe and 33% are in the building shell itself.

Miscellaneous:

One very rapidly growing field in the building industry is that of mobile homes. Since mobile homes are moved about at some stage of their life, weight is very important and consequently a lot of aluminum has been used to minimize this. New high-performance composites are expected to be on the market by 1973, with mechanical properties comparable to those of aluminum but at two-thirds the weight. These may replace aluminum in many applications.

B. CONCRETE

Lightweight structural concrete is relevant to concrete system building, insofar as it allows for the construction of larger units than does normal concrete where the weight of the precast unit (and not its size) is a critical factor with regard to transportation and erection.

Lightweight aggregates have been available for the past 53 years. Historically, lightweight aggregate has been predominantly made from expanded clay or shale and from expanded blast furnace slag.

Fly ash, used successfully in Europe for many years, is a recent addition to the list of lightweight aggregate materials in Canada. The anticipated availability of fly ash aggregate in Ontario as a competitive material to expanded clay, shale and slag lightweight aggregates will, hopefully, ensure price stability. The result could be an increased use of lightweight aggregates by existing and new precast concrete companies in connection with precast concrete building systems.

Regulated-set cement

Regulated-set cement is a hydraulic cement whose setting time can be controlled at anywhere from 1 or 2 minutes up to 30 minutes, with corresponding rapid strength development. It is a modified portland cement that can be manufactured in the same kiln used for manufacture of standard portland cement. It was developed at the Portland Cement Association laboratories and patent protection has been applied for. Regulated-set cements have been produced in limited quantities by several companies in the United States. They are still available only for developmental purposes.

There are at present no standard specifications for regulated-set cement. Additional data is being obtained to

form a basis for such specifications. Mortars and concretes made with regulated-set cement set more rapidly and develop a greater very early strength than comparable mixes made with standard portland cements. Except for these differences, the physical characteristics of the resulting concrete in tests made to date are similar to comparable mixes made with standard portland cements.

The amount of early strength component in the formulation affects the early strength development. In addition to control by basic formulation, the handling time is also influenced by mix temperature. Because of the short handling times and high rate of strength development, these characteristics are little influenced by the ambient temperature to which a particular mix is exposed. Curing procedures are the same as those applicable to standard portland cement concretes.

Another significant factor is the greater heat emission due to the very early and rapid hydration. This may be advantageous or disadvantageous, depending upon the circumstances.

With respect to hardened mortar or concrete, there appear to be no different design considerations from those pertaining to standard portland cement concrete. As a structural material, the observed performance to date is essentially identical to that of comparable conventional concretes.

While the report concentrates on system building, it should be noted that there appear to be numerous other potential uses for regulated-set cement. Some of these are: prestressed and precast elements; vertical slip-forming; fireproofing; lightweight insulating and winter concreting.

Laboratory and field trials are now being carried out (primarily on lightweight insulating concrete) for roof decks, special building materials and precast structural elements. The commercial use of this cement may well result in economies in the production of precast concrete units derived from the more rapid re-use of forms.

<u>Expansive cement for shrinkage-compensating concrete</u>

Expansive cement is a hydraulic cement that expands during the early hardening period after setting. Currently, three types are recognized, designated as Types K, M and S:

Type K consists primarily of calcium silicates, anhydrous calcium, alumino-sulfate, calcium sulfate and free lime;

Type M is comprised of portland cement, calcium aluminate cement and calcium sulfate;

Type S is composed of a portland cement containing a large computed C_3A content and calcium sulfate in excess of the usual optimum content.

The expansive properties of each of these may be varied over a considerable range and the implications of this property are far-reaching. However, the information detailed here is directed primarily to cements that produce shrinkage-compensating concrete.

Expansive cement for shrinkage-compensating concretes is produced in the United States by several companies. It is not yet available in Canada.

There are at present no standard specifications for shrinkage-compensating expansive cements. However, ASTM Committee C-1 on Cement is currently developing such specifications.

The physical characteristics of shrinkage-compensating concretes are generally similar to comparable mixes made with standard portland cements. Under some circumstances slump loss may be greater, particularly if extended mixing times are involved. Strength gain may be low during the expansive period; but, subsequent strengths, modulus of elasticity, freeze-thaw resistance and abrasion resistance are comparable to those obtained with standard cements. Shrinkage-compensating concretes may be more susceptible to sulfate attack, because of their alumina content, than are concretes made with standard portland cement.

When properly cured, the expansion of concrete made with shrinkage-compensating cement virtually ceases during the first week. In some instances, slight additional expansion may subsequently occur. After the primary expansion is completed, the concrete will respond to moisture and temperature changes in the same manner as standard concretes. This means that the shrinkage and expansion on drying and wetting or cooling and heating are comparable in magnitude to concretes made with standard cements.

Concrete may crack as a result of drying or temperature drop. Restraint of expansion should be provided to obtain the crack-reducing advantage of shrinkage-compensating concrete. Restraint of expansion can be applied either externally or internally. The amount of restraint required depends upon the expansion characteristics of the concrete, the design requirements of the element and the environment to which it will be exposed. Research is underway in the PCA laboratories to develop the necessary restraint criteria.

The concrete, during expansion, may be restrained by another slab or structure, by the ground or by reinforcing

steel. Restrained expansion induces a compressive stress in the concrete during the expanding period. This helps to offset the subsequently occurring shrinkage stresses. Future research may establish the degree of expansion required to offset seasonal temperature contraction stresses.

The properties of one type of expansive cement have been utilized as the key factor in a recently developed building system, UNIMENT, which was researched and developed by a company in the United States, and has been franchised for use in Canada.

The concrete, in this case containing lightweight aggregate, is placed around high tensile reinforcing bars between steel forms. During setting, the cement mortar expands sufficiently to place the reinforcement under a predetermined amount of tension. The concrete is correspondingly placed under compression resulting in a high-strength concrete that is stressed in three directions when used for the manufacture of box units. The use of this cement enables box units to be produced with monolithically-cast walls, ceiling and floor elements, as little as two inches thick.

In addition to use in system building, shrinkage-compensated concrete is applicable to the construction of: slabs-on-grade, parking deck structures, water holding structures food processing plants, walls above ground, recreational uses.

At present, rigorous design procedures have not been established for shrinkage-compensating, cast-in-place concrete. In the interim, design procedures for conventional reinforced concrete are being used. Research is underway in the PCA laboratories to determine if special design methods are needed for shrinkage-compensating concrete.

Fibre reinforcement of portland cement paste, mortar and concrete

The current interest in fiber-reinforced materials stems largely from research on the strength of glass fibres. The development of the highly successful composite generally known as 'fibreglass' (but more accurately described as glass-fibre-reinforced plastic) was the result of efforts to utilize the high strength of thin glass fibres. By embedding the fibres in the proper matrix material, it is possible to utilize the strength of virtually all of the fibres.

The mineral fibre asbestos has been combined with portland cement paste to form the successful product called asbestos cement.

Although the elasticity of portland cement paste is too low to utilize the full potential of asbestos fibres, the composite product does have a considerably higher flexural strength than portland cement paste. Commercial asbestos cement products contain from 8% to 16% fibres by volume. The maximum fibre length is about 10 mm, but most of the fibres are considerably shorter.

Only a few countries are important producers of asbestos, and in these countries the better grades are being depleted. Many countries produce no asbestos at all. Consequently, there is considerable interest in finding a suitable substitute.

Glass fibres are being considered as substitutes for asbestos and much research work has been done on this matter. Other research is now in progress to produce glass-fibre-reinforced paste and mortar. The Building Research Station in England has a program for developing suitable ways of incorporating glass fibres in portland cement products. Detailed reports on these British studies are expected to be published soon.

There are two chief problems in the use of glass fibres in portland cement products: breakage of the fibres; and chemical attack of the glass by the high alkalinities found in hydrated portland cements. Both problems are under investigation.

A new approach to the problem of fibre breakage has been developed at the Rensselaer Polytechnic Institute in Troy, New York. The basis of this development is the use of specially treated glass fibre elements mixed with concrete on the site or in a plant. Each element consists of 3,000 filaments each 0.00037 inches in diameter. Each element is treated with a thermosetting resin which protects the individual filaments from the alkaline reactions which occur in hydrated cement.

The effective tensile strength of these elements is six times stronger than mild steel reinforcements.

Nylon and steel fibres have had some consideration for use in concrete. However, there is not much to recommend the use of either of them at this stage. Nylon has some mechanical disadvantages and steel fibres would appear to be too costly.

Polymerization of concrete is a promising avenue of research and developments, and the possibility of combining this with research into fibre reinforcement to produce a common product should not be excluded.

In 1965, the U.S. Bureau of Reclamation commenced a series of experiments in cooperation with the U.S. Atomic Energy Commission to determine the effects of impregnating a liquid monomer into concrete, then initiating the polymerization of the monomer.

Early research indicated that the best results were obtained by initiating polymerization by gamma radiation and that the results of this process were impressive. For

example, when methyl methacrylate is introduced into concrete and irradiated, the compressive strength, tensile strength and modulus of rupture are increased by 256% to 290%. Water permeability is decreased to an insignificant value. Water absorption is decreased as much as 95%. Resistance to abrasion, cavitation, freezing and thawing and the deleterious effects of soluble sulfates and acids showed distinct improvement.

Later test results indicate increase in compressive strength of 350%, in tensile strength of 390% and in flexural strength of 360%. Weight loss during the freeze thaw was only 0.5% after 2420 cycles, which indicates that this material has an extremely good resistance to freeze/thaw action.

Already the use of polymer concrete under certain conditions appears economically feasible for a number of applications including precast beams, wall and floor panels, and loadbearing elements.

Continuing research and development work could well result in significant advances in this area of concrete technology. While the prime objective of the research is to develop this technique to the point where it will be commercially available to produce concrete pipe and for use in water desalination plant construction, all developments will be relevant subjects for detailed study for possible application to concrete building systems.

C. ADHESIVES AND SEALANTS

Many of the new products that will fall in the category of adhesives or sealants are presently in the development stages or undergoing testing to receive approval. The new properties will have better performance characteristics and cost less than older products.

Most adhesives will feature higher strengths, faster bonding and setting, and a reduction in nailing and material required.

Sealants will be more important in system building than the role they now play in conventional construction. With lighter and/or larger components, sealants must accommodate the movement and perform for the age of the structure. Thus, future sealants will need to have properties of adhesion and cohesion in one mix. The new products will contain a high percentage of solids and be extremely elastomeric in nature.

Proprietary products and brand names have not been mentioned to avoid any bias or favouritism. For each specific case where an adhesive or sealant or both is required a separate evaluation of all the products on the market should be made.

D. ASBESTOS

Cement is the most common inorganic binder used to fix asbestos fibres used in building materials. Asbestos-cement products in the past were mainly exterior cladding, but the new products will be of sandwich construction using a foam insulation between the inner and outer sheets. It is expected that this type of component will be marketed for commercial and industrial use before application in residential buildings. Several colours are available and only the jointing needs further development.

At least one system builder in Canada has proposed using molded asbestos cement as an exterior cladding and also for interior partitions and space dividers. Prototypes have not been manufactured to date in order to evaluate their performance. The material is in use on some European systems.

A limited supply of asbestos fibre and a current health scare may restrict the acceptance of these products in the future.

E. BRICKS

The major changes and the greatest developments will not be in the bricks themselves but in the building codes governing the use of brick. The 1965 National Building Code allowed greater use and wider application of clay brick and the 1970 NBC will facilitate greater economies by allowing higher stresses and outlining total design requirements.

Since 1965 the major changes have been the development of 6-inch and 8-inch "Through-The-Wall" (TTW) units. An efficient load-bearing wall is produced when it is combined with load-bearing masonry. There are hundreds of examples of this type of wall construction throughout Canada and in many OHC projects. The frame is eliminated and the brick may, in many cases, constitute the interior wall finish.

As for panelization, Phase IV of a prototype development and investigation for the use of panelized clay brick in load-bearing walls has been completed and the final results will be known in the fall of 1970. Panelized brick construction was used in a demonstration house erected at the 1970 National Home Show.

F. PAINTS

The technology of paint is complex and under constant change. In fact, the new technology includes families of organic and inorganic formulations, applied in a variety of ways and capable of withstanding a broad range of environments and functional requirements. No one paint can meet all conditions of service and esthetics for walls and other surfaces, and if one were developed, it would likely be a compromise and an inferior product.

Many new products are well suited to system building. Skilled applicators, large equipment and a climate-controlled atmosphere are required to achieve a high quality finish in a matter of minutes. However, to obtain the rapid application, the number of colour selections and variations become limited.

The total cost of a finish is the important criterion. Installation costs can be of secondary consideration if the finish requires expensive maintenance and repairs that cancel savings from low initial costs.

Specifications should stress the basic performance needed for the specific functional requirement. Specifying a product name leads to "or equivalent" bidding which may result in inadequate selection from the vast array of products on the market.

G. STEEL

At present, the amount of steel used in the construction of a house is minimal. Mechanical ducts and piping consume the largest percentage of steel beyond appliances and furnishings.

In the future, one will see more widespread use of light-gauge steel floor joists, wall studs and roof trusses. These products will compete with wood and their ability to replace wood will be primarily a function of initial cost.

For the exterior walls, steel cladding has performed most satisfactorily on experimental houses and one can predict the development of steel panels that are prefinished and fully insulated. It is unlikely that weathering steels will be used in housing and particularly public housing because of the staining problems.

One can foresee more use of steel -- in kitchen cabinets, door frames and exterior doors within the next 3 years. Again cost will be the major factor in penetrating the market.

H. WOOD

Plywood stressed-skin panels for external walls, floors and roof are the major new products likely to be introduced by the forest industry before 1973. The advantages will be better control on quality and reduced site labour and material content. The exact economies are not predictable but the panels are well suited for use in system building applications in those geographical areas where their use is not restricted by codes.

Research is being carried out to improve the design and performance criteria of light frame construction and to determine the structural interaction between elements in components and component assemblies using wood.

There are also many products incorporating pieces of wood (i.e., chips, slivers, shavings, etc., and either an inorganic or organic binder) on the market or about to enter the market.

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APPENDIX E: ACKNOWLEDGEMENTS

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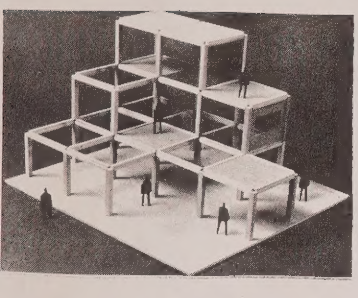

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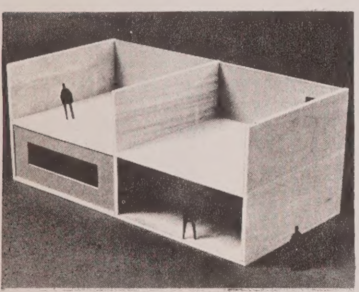

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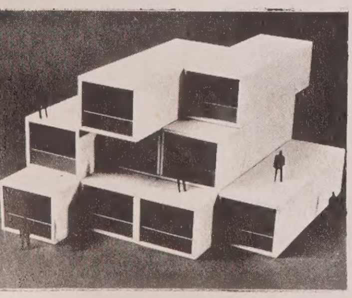

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THE ANSWERS TO THESE AND MANY OTHER QUESTIONS ARE TO BE FOUND IN THE COMPLETE PETER BARNARD AND ASSOCIATES' REPORT ON SYSTEM BUILDING.